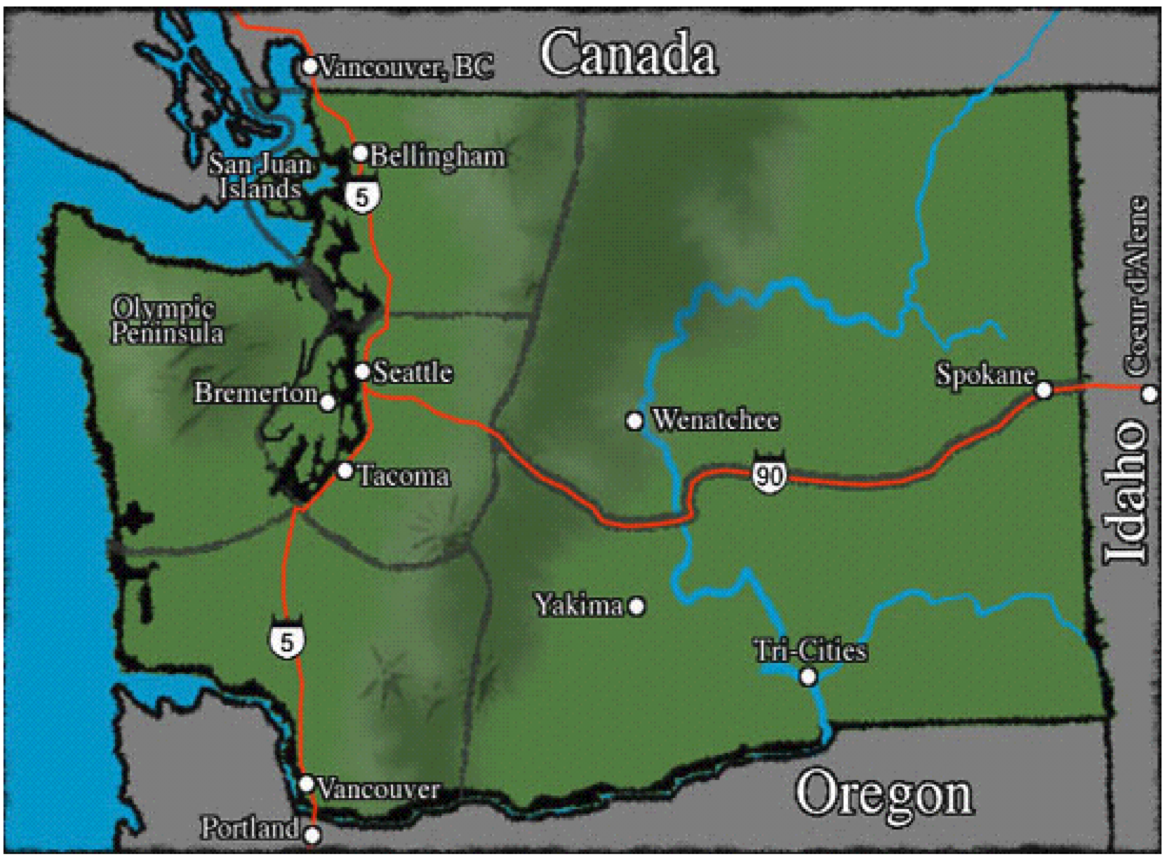
Washington State

Eastern Washington Grain-Hauling Short-Line Railroads



Washington State
Department of Transportation

February 2003

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Prepared for
Washington State Department of Transportation

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Executive Summary

What is the objective of the eastern Washington short-line railroad study?

- To analyze the economic viability of the 372-mile grain hauling eastern Washington rail system known as the Palouse River and Coulee City Railroad (PCC). (See Figure 1 for map of PCC's eastern Washington grain lines.) In 2000 these lines generated 10,700 carloads of traffic.
- To value the public benefits of preserving the PCC system.

What are WSDOT's conclusions and recommendations?

The Washington State Department of Transportation's (WSDOT) conclusions and recommendations are:

- In private ownership the 372-mile PCC rail system is not self-sustaining and is highly susceptible to abandonment.
- The lower cost of rail bulk transport allows the PCC to save eastern Washington shippers $2.17 million per year in reduced freight charges.
- Preserving this rail system keeps more than 29,000 heavy truckloads per year off state and county roadways. Looking over a number of years, the PCC creates an annualized net public benefit of $4.16 million per year in avoided highway truck damage.
- Additional data received since the study shows that the immediate loss of wages and benefits in affected rail-dependent industries has an annual cost of $6.4 million. In addition, potential job losses plus planned jobs that would not be realized could cost another $11.1 million per year in lost wages and benefits.
- Local rural economic development efforts to keep existing firms or lure prospective businesses to rural eastern Washington also benefit from continued rail access.
- The PCC system has an acquisition value (net liquidation/scrap value less outstanding public debt) of approximately $7.45 million. This contrasts against annual public benefits ranging from $12.9 to $23.9 million per year. Consequently, the benefits from purchasing and preserving the system will repay the public in the first year with additional benefits every year thereafter.

- WSDOT supports placing this rail system in public ownership to realize these benefits to the communities, businesses, and shippers in Whitman, Grant, Lincoln, Walla Walla, Columbia, and Spokane Counties. A consortium of port districts and county governments ultimately should be responsible to manage and preserve the PCC at the local level.

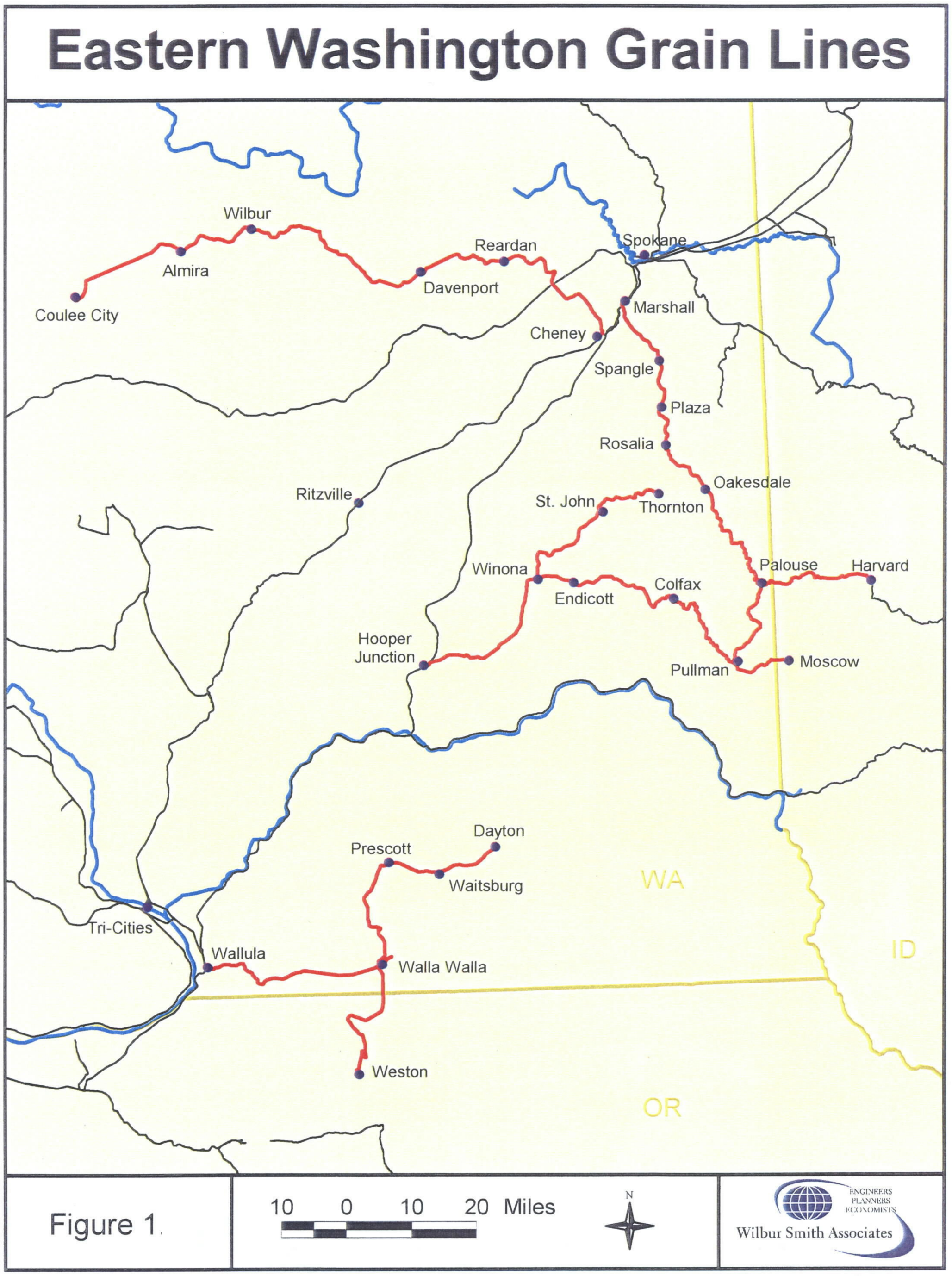

Figure 1.

What is the background of the Palouse River and Coulee City Railroad?

In the summer of 2001, the PCC advised WSDOT that significant sections of its 372-mile eastern Washington rail system would have to be abandoned in the next five years. The PCC's reason was that these rail lines do not and cannot generate enough freight revenues to cover both the costs of rail system ownership and ongoing track maintenance. Ownership costs include PCC's loan payments for the purchase of the branch lines from the Burlington Northern and Santa Fe Railway (BNSF) and Union Pacific Railroad (UP). Maintenance costs include the track rehabilitation expenses needed to cover the decades of deferred track maintenance before their sale. In addition, many of the lines must soon be upgraded to handle the newer and heavier 286,000-pound freight cars that the rail industry is moving towards. More state rail assistance loans would be of no help, because the increased debt burden on the railroad would lead to financial distress.

However, the PCC does believe that enough freight revenue is generated from current rail business to cover the operating expenses of the rail system which includes: normalized track and bridge maintenance, transportation (primarily locomotives and train crew labor), equipment maintenance, and general administrative costs.

The primary purpose of this report is to provide an independent analysis on the viability of the PCC rail system. This evaluation is not predicated upon information provided by the railroad or groups with potential conflicts of interest. The PCC system is analyzed as if it were a hypothetical stand-alone short-line railroad operation providing common carrier rail freight service to branch-line shippers. Independent estimates of track net liquidation values and normalized maintenance costs are derived from detailed field data, track charts, and engineering models.

A second purpose is to provide a firm estimate of how much additional heavy truck roadway damage will result if cargo currently moving over the PCC rail system is diverted to state highways. This would be important to determining the best course of action if WSDOT determined through independent analysis that the PCC system is likely to be abandoned.

Since the eastern Washington short-line railroad study was completed in early fall 2002, WSDOT has undertaken additional analyses and consultations with local ports, county commissions, civic leaders, shippers, and shipper associations. Some of the information reported in this summary reflects that more recent data, especially on wages and benefits that may be lost if the PCC is abandoned.

What are WSDOT's findings?

Is the PCC system viable?

Study results indicate that the PCC needs to generate $4.4 million per year to operate trains, perform normalized track and bridge maintenance, and cover general and administrative expenses. They accomplish this currently through the collection of $4.15 million in annual freight revenues and $0.26 million in annual property lease revenues.

However, there are two significant non-operating costs that the PCC system is unable to cover from existing revenues. One is the debt burden owed by the railroad and the other is the rehabilitation expense of deferred track maintenance from the previous owners (BNSF and UP), along with related 286,000-pound freight car track and bridge upgrades.

The cost of property ownership of the 321-mile[1] PCC is estimated at $1,005,000 per year. This ownership cost does not include any rail line maintenance costs. The annual ownership cost is determined by what the owner of the rail system could net if the property were sold at market value and the proceeds from the sale generated 10.2 percent in interest per year. The 10.2 percent interest is the 2001 American rail industry cost of debt and equity capital according to the United States Department of Transportation. These additional million dollars per year for the cost of ownership of the PCC system trackage is an expense that cannot be covered from existing revenues.

Obviously, if the PCC rail system were in public ownership, the one million dollar private ownership financial burden would be eliminated, significantly improving the probability of the railroad's long-term survival.

1 While the PCC operates 372 miles of rail lines in Washington State, the PCC only owns 321 miles of track. This accounts for the difference in track miles between track miles owned and miles of track to operate and maintain. The remaining 51 miles are owned by other entities such as the Port of Columbia, which owns the 39-mile Walla Walla to Dayton branch. However, the PCC still has the responsibility to operate trains and maintain the track and bridges on the Walla Walla to Dayton branch.

Does the PCC need to catch-up on deferred maintenance?

The other long-term dilemma that faces the PCC system is up to $40 million in track and bridge upgrades required to create a completely renewed and upgraded infrastructure. This is necessitated by years of deferred track maintenance at the hands of the previous rail line owners and also to upgrade the line's capacity to handle the industry's current standard of 286,000-pound railcars. With today's newer and heavier freight cars operating over ancient lightweight rail, there are increasing numbers of low-speed train derailments. The threat of nuisance derailments forces trains to move at restricted speeds, which causes train crew labor expenses to skyrocket, which leads to the rail line becoming too labor intensive and ultimately too costly to operate.

Not every PCC line needs the full 286,000-pound upgrade, but there is a need for considerable infrastructure investment. Assuming the worst case of $40 million spread over 12 years, the PCC would require annual capital expenditures of approximately $3.33 million per year, which threatens the long-term viability of the PCC system. While the revenues generated from freight and property leases can cover normal railroad operating expenses, the railroad needs help catching up on the capital expenditures.

Upgrading track from 10 mph to 25 mph train speeds could significantly reduce train crew labor costs and locomotive expenses. If the majority of these rail lines could be operated at 25 mph, train crew labor cost savings would provide additional funds that could be reinvested into badly needed track and bridge rehabilitation work.

What savings from avoided highway damage is there for the state of Washington?

If the PCC rail system were lost to abandonment, more than 29,000 heavy truckloads per year would be added to state roadways. It is estimated that the damage to these roads will total $4.76 million per year. However, these trucks would pay an additional $598,000 in government roadway user fees. Consequently, the annualized value of the net additional roadway damage expense to the state is $4.16 million per year.

What are the potential economic impacts?

Increased shipping charges

If the PCC system were lost to abandonment, the lower cost alternative of rail shipment would no longer be available. As a result, the cost of shipping products (primarily Washington State grain) produced in this region to market would increase by an estimated $2.17 million per year.

There is also the possibility that water and motor carriers freed of lower cost rail competition would raise rates even more. And while it is difficult to estimate a monetary impact, the higher transportation charges will make it more difficult for Washington products to compete on world markets.

Job and wage losses

Since the eastern Washington short-line railroad study was completed, a review of potential job and wage impacts has been completed based on information provided by port districts, county commissions, and local economic development agencies. They are listed below, calculated on a conservative basis of wages of $10 per hour and 25 percent benefits over a 2,000-hour work year, unless otherwise noted.

Immediate job losses if the PCC is abandoned

It should be noted that many of these losses might occur well before actual abandonment once the industry in question believes it will occur and begins seeking other business locations, if possible.

- Seneca Green Giant cannery at Dayton, Columbia Co.:
  - ◊ 60 full time jobs = 60 x 2,000 x 10 x 125% = $1.5 million
  - ◊ 1,100 part time jobs = 1,100 x 200 hrs x $6.90 = $1.5 million
- Feed mill at Reardan, Lincoln Co.:
  - ◊ 100 full time jobs = 100 x 2,000 x 10 x 125% = $2.5 million
- PCC railroad workers in all served counties:
  - ◊ 35 full time jobs = 35 x 2,000 x 10 x 125% = $0.9 million

Total annual lost wages and benefits are estimated at $6.4 million

Potential job losses if the PCC does not continue operations

- Metal fabrication plant at Airway Heights Industrial Park, Spokane Co.:
  - ◊ 250 full time jobs = 250 x 2,000 x 10 x 125% = $6.25 million
- Plant expansions at Airway Heights:
  - ◊ 150 full time jobs = 150 x 2,000 x 10 x 125% = $3.75 million
- New feed mill at Creston, Lincoln Co. (which would be the town's largest employer):
  - ◊ 45 full time jobs = 45 x 2,000 x 10 x 125% = $1.1 million

Total potential annual lost wages and benefits are estimated at $11.1 million.

Damage to future economic development prospects

The PCC is the main or only local rail service to the counties of Whitman, Walla Walla, Columbia, Lincoln, Spokane, and Grant. Its demise could severely hinder future rural economic development efforts to lure potential plants and industries to this area of high unemployment. Many large employers are rail dependent because they must transport bulky or hazardous (restricted) commodities. The lack of rail service will prevent many rural towns from trying to site such job producers nearby.

What would be the public cost of buying the PCC?

The study reports that the railroad's value is in its net liquidation value. That is, if the railroad were scrapped and all scrap and real estate sold, what would be the amount realized? This so-called net liquidation value (NLV) is reported as $9.8 million in the eastern Washington short-line railroad study. However, since the study was published, the Union Pacific Railroad has clarified that it still owns a portion of the mileage operated by the PCC and that the PCC pays an annual fee for use of the track. Therefore, the net liquidation value has been recalculated as $8.85 million. This includes short segments of track in Idaho and Oregon that generate considerable revenues for the PCC and must therefore be included in any Washington purchase of the line.

The PCC has an outstanding balance of $1.4 million on a Washington State Department of Transportation freight rail assistance loan. Assuming a public purchase of the line to place it in public ownership, the net payment to the owners of the PCC (WATCO of Pittsburg, KS) would then be $7.45 million ($8.85 million less $1.4 million).

Does the price WATCO paid for the PCC enter into the calculation?

No. If WATCO were able to persuade the federal Surface Transportation Board that the line is no longer viable due to declining physical condition and thus be granted the right to abandon it, they could in fact realize the net liquidation value. The only way to avoid the granting of the abandonment would be for some other entity to purchase the line at the net liquidation value.

Would public efforts to preserve the PCC benefit Washington State?

Clearly, yes. Annual public benefits would range from a total of $12.9 million up to $23.9 million if all potential new jobs could be realized. Even the lower figure is more than 50 percent above the $7.45 million it would take to put the PCC into public ownership and prevent its abandonment.

Reduced freight transportation costs	$2.17 million/yr.
Annualized value of net avoided highway damage costs	$4.16 million/yr.
Wages and benefits from direct job losses	$ 6.4 million/yr.
Total Annual Public Benefits ***Incl. direct losses of wages and benefits***	**$12.8 million/yr.**

Wages and benefits from potential job losses	$11.1 million/yr.
Total Annual Public Benefits ***Incl. direct and potential losses of wages and benefits***	**$23.9 million/yr.**

Dictionary of acronyms used in the main report

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
ACP	Asphalt-concrete pavement
BLMR	Blue Mountain Railroad
BST	Bituminous surface treatment
ESAL	Equivalent single axle load
FHWA	Federal Highway Administration
HERS	Highway Economic Requirements System
NAPCOM	National Pavement Cost Model
PCC	Palouse River and Coulee City Railroad
PSC	Pavement Structural Condition (scaled from 0 to 100)
PSR	Present Serviceability Rating (scaled from 0 to 5)
WSDOT	Washington State Department of Transportation
WSPMS	Washington State Pavement Management System

Washington State Department of Transportation

Chapter 1: Viability of Grain-Hauling Short-Lines in Eastern Washington

Introduction

The Palouse River and Coulee City Railroad (PCC) operates 372 miles of light-density lines in eastern Washington. In 2000 these lines generated 10,700 carloads of traffic. Most of these carloads were shipments of grain destined for Columbia River ports.

The PCC has raised the possibility that these rail lines may be targeted for abandonment in the next five years. The company believes that the lines do not generate enough revenue to cover annual debt service and fund track and bridge rehabilitation needs. The PCC has offered to sell its lines to the Washington State Department of Transportation (WSDOT) for their net liquidation value.

The purpose of the *Eastern Washington Rail Study* is to analyze the viability of the PCC system as a private entity and identify the public benefits of preserving rail service on these lines. One of the primary benefits of preserving rail service is the avoidance of increased highway costs resulting from additional truck traffic on low-volume roads. These implications are evaluated in Chapter 2 of this report.

The purpose of this chapter is to assess the economic future of the lines and the options facing the state of Washington. The specific objective of this chapter is to provide an independent analysis of the viability of the rail lines. The analysis presented in this chapter is not predicated upon information provided by the railroad or groups with potential conflicts of interest. The line is analyzed as if it is operated under contract by a hypothetical carrier. Branch-line operating costs are estimated under efficient operating conditions using adjusted Uniform Railroad Costing System unit costs for the Western Region. Trade-offs associated with potential state options are analyzed including acquiring and/or rehabilitating the line.

Rail Lines Subject to Future Abandonment

The PCC was created from a series of line sales by the Burlington Northern and Santa Fe Railway (BNSF) and the Union Pacific Railroad (UP). The PCC network consists of fours sets of lines or subsystems:

1. The Cheney-to-Coulee City line
2. The Marshall-to-Pullman line
3. The Blue Mountain Railroad North
4. The Blue Mountain Railroad South

The Coulee City line is 108 miles in length. It is also known as the Central Washington (CW) Branch. The Marshall-to-Pullman line is 76 miles long. It is part of the old Palouse and Lewiston (P&L) line. A branch of this line, known as the Washington, Idaho, and Montana (WI&M), extends eastward from Palouse a distance of 47 miles into Bovill, Idaho. The northern division of the Blue Mountain Railroad (BLMR) runs from Hooper Junction through Winona and Colfax to Moscow, Idaho.[1] A short branch of this line runs northeast from Winona to Thornton, a distance of 31 miles. The southern division of the Blue Mountain Railroad extends from the UP mainline at Wallula Junction to Walla Walla, where it connects with another line running from Dayton, Washington to Weston, Oregon.

Cheney-to-Coulee City Line

This line was sold to PCC by BNSF in 1996. It connects to the Spokane-Pasco mainline at Cheney. From Cheney the line runs through Medical Lake and Hite on its way to Reardon. From Reardon westward, the line parallels US-2, running through Davenport, Creston, Wilbur, and Hartline before terminating in Coulee City (Appendix A).

Along the way, the line runs through three counties. Most of the Cheney-to-Reardon segment is located in Spokane County. The entire segment from Reardon-to-Almira falls within Lincoln County. The westernmost segment from Almira-to-Coulee City lies mainly in Douglas County.

[1] The segment of the former Union Pacific line that ran from Pullman to Moscow has been abandoned. The PCC currently provides service between Pullman and Moscow over former BNSF tracks that were included in the P&L line sale.

Shippers

With the exception of a few carloads of farm implements, grain is the only commodity originated on the line. Five companies own elevators on the line:

- Central Washington Grain Growers
- Reardon Grain Growers
- Odessa Union
- Davenport Union
- Almira Farmers Warehouse

Central Washington Grain Growers operate 26-car loading stations at Coulee City, Hartline, Almira, Creston, and Wilbur. They also have a single-car facility in Hanson. Reardon Grain Growers operate elevators at Reardon and Hite. Reardon is a 26-car shipper. However, Hite is a single-car shipper. Davenport Union operates 26-car stations at Davenport and Mondovi. Odessa Union has a 26-car facility at Davenport and a smaller one in Rocklyn. Almira Farmers Warehouse operates a 26-car station in Almira and single-car facilities in Hanson and Hartline. Issak Brothers Grain—a 26-car shipper—is located at Cement.

Another potential shipper, Rainbow Chemical, is located on the line. However, all inbound fertilizer shipments currently move by truck.[2]

Density and Operations

The Coulee City line is approximately 109 miles long. The entire line is rated at FRA Class 2. The maximum operating speed is 25 mph.

In the most recent two years of operation, the line generated 39 carloads per mile. Approximately 4,000 carloads were originated in 2000. Much of this traffic originates from the western end of the line. The crew usually travels the length of the line during a train trip. The speed and line length result in frequent crew layovers.[3]

[2] Although several varieties of fertilizer are used in the area, Anhydrous Ammonia is the predominant chemical moved into the facility.
[3] When the crew's hours of service are exhausted, they are lodged overnight at a convenient city. Alternatively, a replacement crew is transported via motor vehicle from Cheney to the location where the original crew's time expired. The expired crew is then transported via motor vehicle to Cheney.

Although many of the stations on the line consign 26-car shipments, they lack the track configuration to accommodate a 26-car block in a single switch. Consequently, the train crew must separate the 26 cars into two or more blocks before spotting them.[4]

Car Ownership

The freight cars are provided by BNSF. A mileage rental of 5 to 6 cents is assessed for each car-mile traveled over the line. However, time-related car-hire charges are rarely incurred. The BNSF allows five free days. During this period, an empty freight car must be delivered from Cheney to the station, loaded by the shipper, and returned to Cheney. If the loaded car isn't returned within five days, an hourly car-hire charge is assessed.

Rails

The curved track is built with 100-pound, 112-pound, and 115-pound rails. Most curves include bolted rails. However, some 112-pound continuous welded rail (CWR) has been placed in curves.

The tangent sections of the Cheney-to-Coulee City line are built with 85-pound and 90-pound bolted rail. Approximately 80 miles of this rail was manufactured prior to 1915. These rails were milled before many of the modern advances in metallurgy occurred, such as controlled cooling. Rail mills did not commence widespread production of steel rails using this technique until 1931. As a result, internal transverse fissures have been found in many older rails.

Transverse fissures start from minute shatter cracks in the steel and are propagated under heavy loads. Many of these defects can be located by rail detector cars, which have been run over the line periodically. The railroad acknowledges that defects have been found in some of the 85-pound and 90-pound rail sections.

[4] It may require 30 minutes for the crew to spot all 26 cars. Afterwards, shippers use their own equipment to reposition cars for loading and subsequent pick up by the railroad.

Roadbed and Structures

The Cheney-to-Coulee City line was originally constructed in 1888. At that time, track engineers did not have the benefit of modern soil analysis techniques, construction methods, or heavy equipment. The original roadbed was constructed of materials borrowed from along the right of way or transported short distances in wagons.[5] It is unlikely that any substantial subgrade reconstruction or stabilization projects have been undertaken on the line since the date of construction.[6]

The characteristics of native soils found in the region are summarized in Appendix B. The segment of the line from Hartline to Coulee City is a potential concern. Apparently, BNSF—the former owner—embargoed sections of the line periodically.

There are 22 timber bridges on the line. However, they are short span bridges. For the most part, they cross gullies that accommodate runoff during heavy rains and floods. The bridges were inspected earlier this year and no major deficiencies were found. They should continue to perform adequately with routine maintenance and inspection.

Marshall-to-Pullman Line

This line was sold to PCC by BNSF in 1996. The line originally ran from Marshall to Arrow, Idaho via Pullman and Moscow. The Moscow-to-Arrow segment was out-of-service at the time of the sale. The area was flooded and there were numerous washouts on this segment.[7] Service was never reinstated.[8]

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[5] On the positive side, the roadbed may have benefited from gradual consolidation under traffic over the years. Unfortunately, in most cases, in-service consolidation isn't uniform. As differential consolidation occurs under traffic, chronic problem areas tend to emerge. These problems may be especially prevalent in areas of soft saturated soils.

[6] A common practice after initial construction was to transport better soils and subballast materials to the line by rail car. However, these materials were usually dumped onto the existing subgrade or subballast. In essence, the primary strategy was to improve the original roadbed by creating overlying layers of better material. Unfortunately, this approach did not correct any fundamental weaknesses of the original roadbed soil. Over the years, many older branch lines have been built up periodically by dumping new ballast on top of existing material.

[7] The Moscow-to-Arrow segment had previously been abandoned by BNSF but had not been salvaged at the request of the states of Idaho and Washington.

[8] A report by Wilbur Smith Associates—*Strategies for Long-Term Viability*, June 2001—concluded that the Moscow-to-Arrow segment "could have played a major role in a forest product movement, which would have provided a significant revenue boost for the lines. A grain shuttle to the port terminals in Lewiston, Idaho was also being considered at the time."

In 2000, 1,946 carloads were originated from stations on the Marshall-to-Pullman line.[9] From north-to-south, the stations on this line include: Spangle, Plaza, Rosalia, McCoy, Flaig, Oakesdale, Belmont, Eden, Palouse, and Fallon. Cooperative Agriculture Producers own elevators at Spangle, Plaza, Rosalia, McCoy, and Oakesdale. Plaza and Oakesdale are 26-car shippers. In addition to these facilities, Cenex Harvest States Coop owns a 26-car elevator in Spangle. Whitman County Growers operate a 26-car facility in Fallon. Palouse Grain Growers and Wallace Grain & Pea Company have smaller facilities in Palouse. In addition to the grain traffic, some forest products traffic is originated on the WIM subdivision in Idaho.[10]

The Marshall-to-Pullman line includes 34 miles of 112-pound continuous welded rail. The rail weights vary on the remaining 46 miles of the line, ranging from 90 to 115 pounds. In general, the rail weights are not an issue on this line.

Blue Mountain Railroad South

In total the Blue Mountain Railroad (BLMR) South operates more than 80 miles of railroad. BLMR connects with the UP at Zanger Junction. From Zanger Junction, the line extends 27.5 miles to Walla Walla. A branch runs from Dayton through Walla Walla to Weston, Oregon. However, this line is operated only as far as Milton Freewater, Oregon.

Most of the traffic originated from stations in Washington comes from shippers located in Dayton and Walla Walla. Seneca Foods in Dayton is a shipper of canned vegetables. Agri Pak and Americold ship food products from Walla Walla. Northwest Grain Growers operate a 26-car elevator in Prescott and Columbia County Grain Growers operate a 10-car facility in Dayton.

With the exception of .3 of a mile, the rails on the Zanger Junction to Walla Walla segment weigh at least 110 pounds per yard. The segment includes nearly 13 miles of 133-pound rail. However, the 38-mile segment from Dayton to Walla Walla is built with 75-pound, 80-pound, and 85-pound rails. Because of the light rail, the maximum car weight on this segment is 263,000 pounds.

[9] In this study, the portion of the line from Marshall-to-Pullman is analyzed as a segment. However, the traffic originated at Pullman is assigned to the BLMR North.
[10] The freight cars used on this line are provided by BNSF subject to the mileage rentals and free time mentioned earlier.

Blue Mountain Railroad North

The BLMR North connects with UP at Hooper Junction. From Hooper Junction, the railroad runs east for 79 miles, passing through Winona, Colfax, and Pullman on its way to Moscow, Idaho. A branch of this line runs northeast from Winona to Thornton, a distance of 31 miles. In addition, the BLMR has trackage rights over UP from Hooper Junction to Wallula.

In 2000 the northern BLMR lines generated 3,447 carloads of traffic. Most of this traffic was grain. However, some shipments of farm machinery, fertilizer, and coal moved over the line. Three grain elevators are located on the Hooper Junction to Colfax segment: Whitman County Grain Growers at Mockonema, Wheat Growers of Endicott at Winona, and Knott Brothers Elevator at Winona. All three are single-car shippers.

Three 25-car shippers are located on the Thornton branch: St. John Grainer Growers at St. John, St. John Grainer Growers at Willada, and Whitman County Grain Growers at Thornton. The remaining elevators are single-car shippers. Latah Grain Company owns an elevator in Moscow. McGregor Company in Willson is a receiver of farm chemicals. Washington State University in Pullman is a receiver of coal shipments.

The northern BLMR lines are built primarily with jointed rails. The 52-mile segment from Hooper Junction to Colfax includes approximately 20 miles of 100-pound rail, 20 miles of 90-pound rail, 7 miles of 133-pound rail, and 5 miles of 131-pound rail. The remaining rail sections weigh 60 to 75 pounds per yard. The 28-mile segment from Colfax to Moscow includes approximately 26 miles of 90-pound rail. The remaining rail sections on this segment weigh 60 to 131 pounds per yard. The 31-mile segment from Winona to Thornton includes approximately 27 miles of 75-pound rail. The remaining rail sections on the Thornton branch weigh 100 to 133 pounds per yard.

The viability of the PCC rail lines is dependent upon many bottom-line factors including: (1) the cost of operations, (2) fixed costs, (3) revenues, and (4) off-branch costs. In addition, the potential for rail traffic growth is important. Trends in grain production and marketing, truck-barge competition, and economic output will affect the viability of the lines.

The remainder of this chapter focuses on the profit potential of the lines as private railroad entities. The analysis process and techniques are described in depth for the Cheney-to-Coulee Line. The same procedures and techniques are applied to the BLMR and Marshall-to-Pullman lines.

Analysis of the Cheney-to-Coulee City Line

Revenue

Grain is the predominant commodity originated at stations along the line. The 26-car wheat rate to Portland is $1,265 per car when shippers use 263,000-pound cars.[11] The rate increases to $1,366 per car when wheat is shipped in 286,000-pound cars. However, because of its greater payload capacity, the average rate per ton is lower in the larger cars. With typical load factors, the rate per ton is $12.30 in 286,000-pound cars versus $12.65 per ton in 263,000-pound cars.[12]

The rate must be divided among two railroads. The PCC's revenue division is $400 per carload. The BNSF receives $966 for wheat shipments in 286,000-pound cars and $865 per car for shipments in 263,000-pound cars.

Off-Branch Costs

Although much of the wheat originated on the line moves to Kalama and Longview, Portland is the most frequent destination. In this section of the chapter, the cost of moving wheat over the BNSF system from Cheney to Portland is analyzed using the Uniform Railroad Costing System (URCS).

The URCS is a general-purpose costing system used by the Surface Transportation Board (STB). Each year, the STB applies Phase II of URCS to each Class 1 railroad's expense and operating statistics using the most recent year of validated data. The result of the Phase II analysis is a series of unit costs that are stored in Worktable E.

Worktable E is the starting point for an actual cost analysis. The URCS software uses E-Table factors to estimate the variable and fully allocated costs of a movement. The fully allocated cost of a shipment includes the variable cost plus a percentage allocation of common and fixed costs to each shipment. Theoretically, if the rate for each movement on a railroad's system equals its fully allocated cost, the carrier will earn adequate revenues including a return on investment.

[11] The rates used in this analysis were in effect as of May 31, 2002.
[12] This example assumes that the 286,000-pound car carries 111 tons of wheat while the 263,000-pound car hauls 100 net tons.

Operational Assumptions

Several operational assumptions were made during the cost analysis:

- The cars are dropped off and picked up at Cheney by the Spokane-Pasco local;
- At Pasco, an intertrain switch occurs as the cars are sorted according to destination and drop order; and
- Each car is assumed to move the same number of loaded and empty miles per trip—i.e., the empty return ratio is 1.0.

Revenue-to-Off-Branch Cost Comparisons

The estimated variable cost for the Cheney-to-Portland movement is $573 per car (Table 1). The fully allocated cost of $779 per car reflects the BNSF's constant cost ratio of 1.36.

As Table 1 shows, the BNSF's margin per car is about $393 for shipments in 286,000-pound cars. However, when fully allocated costs are considered, the additional contribution of the wheat movements is $187 per car. Moreover, the profit margins drop when 263,000-pound car rates are considered—and these margins may be overstated. As discussed later the BNSF internalizes the car-day cost associated with its cars when used on the Coulee City line.

Table 1. Revenue-Cost Comparisons for Cheney-to-Portland Movement via BNSF

	286,000-lb Car	263,000-lb Car
Variable Cost	$573	$549
Fully Allocated Cost	$779	$745
Revenue	$966	$865
Margin over Variable Cost	$393	$316
Margin over Fully Allocated Cost	$187	$120

On-Branch Operating Costs

In this study, the rail networks are analyzed as if they are operated by a hypothetical efficient carrier. This operator could be the PCC or another short-line railroad. The hypothetical carrier interchanges traffic with BNSF and UP at designated gateways. Variable on-branch costs (excluding track maintenance and ownership costs) are estimated using adjusted URCS costs for the Western Region of the United States.

Western Region URCS

In addition to individual carrier files, the STB creates composite Worktable E files for the Western and Eastern Regions. The Western

Region includes BNSF and UP. It also includes two smaller Class 1 railroads: Soo Line and Kansas City Southern (KSC). The STB uses URCS regional costs whenever a Class 2 or Class 3 railroad is involved in an interline movement. In these cases, regional costs are applied to the short-line portion of the movement.

The URCS unit costs used in this study are adjusted and applied to train operations over the Coulee City line. Track maintenance and ownership expenses are removed from the unit costs before they are used in the branch-line analysis. The hypothetical carrier is assumed to interchange cars with BNSF at Cheney and operate the line in much the same way that it is operated now.

Operational Cost Categories

The URCS unit costs fall into two broad categories: (1) running and (2) switching and terminal.[13] Running costs are associated with the movement of road trains. Switching and terminal costs are associated with the spotting, pulling, loading, and unloading of freight cars at stations on the line and the interchange of freight cars with BNSF at Cheney.

Running Costs

Running costs are related to:

- Distance (train-miles)
- Weight and distance (gross ton-miles)[14]
- Vehicles and distance (locomotive-miles and car-miles)

[13] With the exception of crew wages, the expenses in each category are separated among operating (OPR), depreciation, rentals and leases (DRL), and return on investment (ROI).
[14] Track maintenance costs also are a function of weight and distance and thus are assigned to gross ton-miles. However, in this analysis, the track maintenance and ownership costs are eliminated from the gross ton-mile unit costs and applied separately.

In the URCS methodology, fuel, locomotive maintenance, and locomotive servicing expenses are distributed among gross ton-miles and locomotive-miles. The gross ton-mile unit cost also includes train administration and shop and machinery costs. The locomotive-mile unit cost also includes:

- Locomotive depreciation
- Rentals and leases of locomotives
- Return on investment of locomotives
- Locomotive administration
- Locomotive machinery and shop costs

Train-mile costs are solely a function of distance and are not related to the number of cars in the train or the weight of the train. In URCS, train-mile costs are separated between *crew* and *other*. The Western Region crew cost includes an average wage of $5.50 per train-mile. However, an additional $1.80 in crew-related expenses is included in the unit cost. These items include supplies, travel-related expenses, and other materials or services related to train crew operations.

Crew fringe benefits are distributed among the other train-mile, gross ton-mile, and locomotive-mile unit costs. These allocations reflect a fringe benefit ratio of .34. Other train-mile costs also include dispatching, train administration, train inspection and lubrication, and operation of signals, interlockers, and crossing protection.

Switching and Terminal Costs

Switching costs are incurred during the spotting, pulling, and sorting of freight cars. In URCS all switching costs are reflected in the engine-minute unit cost, which includes:

- Switching track maintenance and ownership
- Locomotive maintenance, servicing, depreciation, rentals, leases, and return on investment
- Crew costs
- Train fuel
- Administrative overhead

Switching track maintenance and ownership expenses are removed from the engine-minute cost before it is used in the branch-line analysis. There are two main justifications for this adjustment: (1) most industry switching track is maintained by shippers; and (2) the cost of maintaining turnouts is included under normal track maintenance. The cost of yard track maintenance and ownership at Cheney is included in the engine-minute cost as a proxy for yard fees.

Terminal costs include station clerical and car ownership. Station clerical activities include the processing of waybills, claims, and related shipment records. Within URCS station clerical costs are computed on a carload basis. However, car ownership costs are computed on a car-mile and car-day basis. The car maintenance and ownership costs associated with switching activities are assigned to the car-mile yard unit cost. The time-related aspects of freight car deterioration and return on investment are included in the car-day unit cost.

Operational Assumptions

Most of the carloads originated on the line are consigned in 26-car blocks. Typically, several 26-car units are shipped each week. According to the PCC, the train size is usually 52 cars. A typical train is made up of two 26-car blocks. Occasionally, a train will include a 26-car unit and mixed single cars. In this analysis, the average train size is assumed to be 50 cars. Each freight car is assumed to spend four days on the line. This allows one day for delivery, two days for loading, and one day for the return trip to Cheney.

Switching Time Adjustment

The average time required to spot or pull a car at an industry siding in the Western Region is 6.4 minutes. However, considerable economies are involved in switching a car block versus a single car. Thus, an adjustment is needed to the regional average.

An analysis of waybill data reveals that 85 percent of the cars originated on the line are 26-car shipments. The remaining 15 percent are individual car shipments. In the URCS method, the average switching minutes per car is reduced by 50 percent for a multi-car shipment. After this adjustment, the average switching time for a 26-car block drops from 6.4 to 3.2 minutes per car.

In the URCS method, aggregate switching time reductions for multi-car and unit-train shipments are added to the regional average to arrive at a switching factor for individual cars. After this adjustment is made, the estimated switching time for an individual car increases from 6.4 to 9.3 minutes. This value is very close to a long-standing rule-of-thumb; that it takes about 10 minutes to spot or pull an individual car at an industry siding.

When these switching factors are weighted by the percentages of multi-car and single-car traffic mentioned above, the result is an adjusted switching time of 4.1 minutes per car. This estimate allows ample time for the crew to spot and pull 50 cars and accommodate unusual circumstances such as an occupied sidetrack.

Locomotives per Train

A key factor in the running cost analysis is the number of locomotive units per train. The number of units depends on the trailing tons in the train and the ruling grade. As the train moves west, it must ascend a 1.5 percent grade at milepost 88 in the vicinity of Almira. However, the train is hauling empties. On the return trip with loaded cars, the train must ascend several 1.2 percent grades with more than 6,500 trailing tons. The locomotive requirements for these loaded uphill movements determine the number of units needed on the line.

According to the PCC, four units are used on eastbound trains. These units range from 2,000 to 2,500 horsepower. They are similar to ones that a hypothetical carrier would use on the line. For example, the GP39 is a model used frequently in branch-line service. The GP39M, which is part of the BNSF fleet, is rated at 2,250 horsepower (hp).

The determination of a tonnage rating requires the calculation of train and locomotive resistance factors. The Davis Formula is used for this purpose (Appendix C). Train resistance is measured in pounds per ton. It reflects many forces such as: (1) rolling resistance, (2) flange resistance, (3) journal (axle) resistance, (4) track resistance, (5) air resistance, and (6) curve resistance. Locomotive resistance is similar to train resistance, except that it results from the locomotive's own weight. The total resistance to be overcome by a locomotive includes all other resistance plus *grade resistance*. Generally speaking, unit grade resistance is about 20 pounds per ton for each percent grade.[15]

Table 2 shows the calculation of a tonnage rating for a hypothetical 2,250-horsepower locomotive that might be used on the eastbound 1.2 percent grades. The locomotives are assumed to be hauling 50 loaded covered hopper cars with an average net load of 103 tons. The normal and grade resistance are added to arrive at a total freight car resistance of 26.45 pounds per ton. The normal train resistance was computed from the Davis Formula for a 135-ton loaded covered hopper car. The normal locomotive resistance was computed from the Davis Formula for a 130-ton locomotive.

[15] Hay, William W. *Railroad Engineering*, 2nd Edition, John Wiley and Sons, 1982.

Two other concepts are central to the calculation of a tonnage rating: (1) tractive effort and (2) drawbar force. The tractive effort of a locomotive (i.e., the driving force exerted at a given speed) is computed as: *308hp/v*, where *v* is the velocity or train speed. The tractive force of 49,500 pounds shown in Table 2 assumes a speed of 14 mph on the grade. Locomotive drawbar force is the remaining force available to pull the freight cars after locomotive resistance has been overcome. Drawbar force is computed by subtracting locomotive resistance from tractive effort. In the final step of the calculation, a tonnage rating is computed by dividing the drawbar force (in pounds) by the train resistance (in pounds per ton).

As Table 2 shows, the tonnage rating for a 2,250-horsepower locomotive on the eastbound grade is 1,733 tons. However, 50 135-ton cars produce a trailing weight of 6,750 tons. Thus, four locomotives of this horsepower class are needed to pull the loaded train.

Table 2. Estimated Tonnage Rating for 2,250-Horsepower Locomotive

Freight Car Resistance	
Normal Resistance / Ton	2.45
Percent Grade	1.2
Grade Resistance / Ton	24
Total Resistance per Ton	26.45
Locomotive Resistance	
Resistance / Ton	4.12
Locomotive Weight	130
Locomotive Resistance	535.6
Grade Resistance	3,120
Total Locomotive Resistance	3,656
Locomotive Horsepower	2,250
Minimum Grade Speed	14
Tractive Effort	49,500
Locomotive Drawbar Force	45,844
Tonnage Rating per Unit	1,733

Calculation of On-Branch Running Cost

After determining the locomotive requirements, the on-branch running costs can be calculated. This calculation is documented in Table 3, which shows the logic of the calculations as well as the sources of the values used. For example, the locomotive cost per train-mile (Line 6) is the product of the URCS unit cost per locomotive-mile (Line 4) times the average locomotives per train (Line 5).

All of the unit costs are derived from the Western Region Worktable E shown in Appendix D. For these factors, the source column describes the Worktable E location. For example, E1P1 refers to Worktable E1, Part 1.

As noted earlier, all running track maintenance and ownership costs have been removed from the gross ton-mile unit cost shown in Table 3. As shown in Line 9, the running cost per train-mile is approximately $22, exclusive of car ownership costs. This equates to a round-trip cost of $4,776 for a train movement to the end of the line and back (Line 11).

Table 3. Estimated Train and Car Running Costs Incurred on the Cheney-to-Coulee City Rail Line

Line	Cost Factor	Source	Value
1	Unit Cost per Gross Ton-Mile	E1P1	$0.00075
2	Average Gross Trailing Tons	Computed	4,163
3	Gross Ton-Mile Cost per Train-Mile	L1xL2	$3.14
4	Unit Cost per Locomotive-Mile	E1P1	$2.84
5	Avg. Locomotives per Train	Computed	4
6	Locomotive Cost per Train-Mile	L4xL5	$11.36
7	Crew Cost per Train-Mile	E1P1	$6.81
8	Other Train-Mile Unit Cost	E1P1	$0.59
9	Total Cost per Train-Mile	L3+L6+L7+L8	$21.91
10	One-Way Trip Distance	Assumed	109
11	Train Running Cost – Round Trip	L9xL10x2	$4,776
12	Unit Cost per Car Mile – Running	E1P2	$0.050
13	Car-Mile Cost per Car – Round Trip	L10xL12x2	11
14	Car Days Running – Round Trip	Assumed	2
15	Car-Day Unit Cost	E1P2	$15.07
16	Car-Day Cost per Car – Running	L14xL15	$30.13
17	Train & Car Running Cost per Car	L11/50+L13+L16	$136.46

The car ownership cost per mile is 5 cents (Line 12). Thus, mileage-related car-hire costs are relatively insignificant. However, it requires a day to deliver the empty cars and a day to haul them back to Cheney. Thus, the car-day running costs amount to $30 per car (Line 16).

Altogether, the variable train running cost for this movement is $136 per car. However, it is important to remember that track maintenance and ownership costs have been removed from the gross ton-mile unit cost. Moreover, switching and terminal costs have yet to be considered.

Calculation of Switching and Terminal Costs

Switching and terminal costs for the hypothetical branch-line operation are shown in Table 4. For reasons stated earlier, switching track maintenance and ownership expenses have been removed from the URCS engine-minute cost. With this adjustment, the operational switching cost is approximately $27 per car (Line 4). Another $14.70 in station clerical cost is incurred for each carload. The remaining costs are car ownership expenses.

Table 4. Estimated Switching and Terminal Costs Incurred on the Cheney-to-Coulee City Rail Line

Line	Cost Factor	Source	Value
1	Engine-Minute Cost	E1P1	$3.33
2	Switching Minutes per Car	Assumed	4.1
3	Spotted-to-Pulled Ratio	E2P1	2
4	Switching Cost per Car: Industry	L1xL2xL3	$27.28
5	Car-Miles per Switch: Industry	E2P1	4
6	Unit Cost per Car-Mile: Switching	E1P2	$0.13
7	Car-Mile Cost per Industry Switch	L5xL6xL3	$1.03
8	Car-Day Unit Cost	E1P2	$15.07
9	Car Days at Industry	E2P1	2
10	Car-Day Cost: Industry	L8xL9	$30.13
11	Terminal Cost per Car	E1P1	$14.70
12	Switching & Terminal Cost per Car	L4+L7+L10+L11	$73.15

As shown in Table 4, the use-related deterioration of a car while being switched is 13 cents per mile. A car is assumed to travel 4 miles during a switch, including the distance traveled from the main track and any spotting and subsequent repositioning of the car while it's being loaded. Even with this allowance for car movement, the ownership cost associated with an industry switch is relatively insignificant. However, since each car spends two days in the loading process, another $30 is incurred in car ownership cost.

Altogether, on-branch switching and terminal costs amount to $73 per car. This estimate includes the cost of throwing switches and other operational expenses associated with switching activities. However, it doesn't include switching track maintenance and ownership costs.

Calculation of Interchange Costs

Interchange costs include the cost of assembling empty cars into a road train at Cheney, plus the cost of sorting the loaded cars after they are returned to the yard. In this analysis, it is assumed that the branch-line operator is assessed a yard usage fee. Therefore, switching track maintenance and ownership costs are included in the engine-minute cost (Line 3, Table 5).

As shown in Line 9 of Table 5, the estimated interchange cost is $34 per car. This estimate includes engine switching and car ownership costs incurred by the short-line operator. However, it doesn't include interchange costs incurred by BNSF. BNSF's expenses are reflected in the off-branch cost.

Table 5. Interchange Cost per Car

Line	Cost Factor	Source	Value
1	Switch Engine-Minutes per Car	E2P1	1.76
2	Empty Return Ratio	Assumed	2
3	Engine-Minute Unit Cost	E1P1	$5.28
4	Switching Cost per Car	L1xL2xL3	$18.62
5	Car Miles per Switch	E2P1	2.75
6	Car-Mile Cost per Car	L5x$0.14	$0.71
7	Car Days per Switch	E2P1	0.5
8	Car-Day Cost per Car	L7xL2x$20.95	$15.07
9	Interchange Cost per Car	L4+L6+L8	$34.39

Summary of On-Branch Operational Costs

In summary, the estimated cost for the hypothetical branch-line operator is $244 per car. This includes $75 in car-day costs. In the current interline arrangement, BNSF forgives the time-related portion of car-hire charges if the car is returned to Cheney within five days. If the time portion of car-hire charges is excluded, the branch-line operator's cost drops to $169 per car. However, this arrangement merely shifts the cost responsibility to the off-branch portion of the movement.

The operational scenario described in this paper is perhaps the most efficient one possible with the exception of true unit train operations. In actuality, it may not be possible for a railroad to consistently attain such operational efficiency. Therefore, the cost estimates should be interpreted as the lowest ones possible under efficient operating conditions.

Several caveats must be noted regarding the costs presented in this section:

- They include variable train, car ownership, and clerical costs only;
- Track maintenance and ownership costs have yet to be considered;
- Certain overhead costs included in the URCS unit costs may not be incurred on the Coulee City line; and
- The switching factor used in this study provides ample time for the crew to accommodate unusual circumstances.

In the final analysis, $244 per car is felt to be a reasonable estimate of the running, switching, and terminal costs incurred on the line under efficient operating conditions.

Maintenance of Track and Bridges

Normalized (annualized) track maintenance is a very important factor in branch-line viability. Normalized maintenance reflects the annual activity level needed to maintain a track to a specified standard. In actuality surfacing and other program work is undertaken at intervals. This discontinuous approach is cost-effective and practical.

In a normalized maintenance estimate, it is assumed that a consistent number of track assets is renewed or replaced each year—e.g., so many miles are surfaced and so many crossties are renewed each year.[16] Normal maintenance assumes that the track is in a condition from which it can be maintained with a fairly uniform annual schedule of activities. Corrective track work is classified as *rehabilitation* or accelerated maintenance.

[16] Normalized maintenance costs are sometimes discussed in relation to FRA track safety classes. However, FRA track standards are not necessarily the same as normal track maintenance standards, which are intended to preserve a line in perpetuity.

Data Sources

The normalized maintenance costs presented in this section have been derived from multiple data sources including:

- A detailed engineering analysis of the line performed by Russell Abbott of Wilbur Smith Associates (Appendix E);
- A hi-rail trip of the line in conjunction with a review of track profile charts;
- Equated track maintenance factors published by the American Railway Engineering and Maintenance of Way Association (AREMA);
- Telephone interviews with persons familiar with the line; and
- Telephone interviews with short-line railroads that operate lines similar to the ones under study in eastern Washington.

The track analysis begins with an examination of rail maintenance needs. Tie, ballast, surfacing, and other program work are considered later.

Assessment of Rail Condition and Performance

As noted earlier, the curved sections of the track are built with 100-, 112-, and 115-pound rails. Gage face wear and head height loss are the primary concerns with curve rails. Under light traffic loads, these rails are expected to have remaining service lives of up to 100 years (Appendix E).

The tangent rail sections pose different problems. In an evaluation of the line conducted in 1999, Wilbur Smith Associates (WSA) concluded that the remaining life of the 81 miles of 85- and 90-pound bolted rail manufactured prior to 1915 is 10 years or less. In a separate study, Casavant and Tolliver (2001) concluded that this rail would not perform for very long under 71,000-pound axle loads and recommended that much of it be replaced with heavy rail as part of a short-line track modernization program.[17]

Performance of Light Rail Sections

In assessing the viability of the Coulee City line, it is important to consider how the light rail will perform under 286,000-pound cars. *Deflection* is a widely used track performance criterion. As a heavy car moves over a rail line, the track deflects beneath it. Vertical deflection is the best single indicator of track strength, life, and quality.[18]

[17] Casavant, Ken and Denver Tolliver. *Impacts of Heavy Axle Loads on Light Density Lines in the State of Washington*, March 2001.
[18] Hay, William W. *Railroad Engineering*, 2nd Edition, John Wiley & Sons, 1982.

The American Railway Engineering and Maintenance of Way Association (AREMA) recommends a maximum deflection of one quarter-inch for heavy track with reasonably firm subgrade.[19] The limit of desirable deflection for track of light construction is .36 inches.[20] Track that deflects .40 inches or more will deteriorate quickly under heavy axle loads.[21]

The performance of light rail can be simulated with equations developed by the American Railway Engineering Association Committee on Track Stresses. These deflection equations have been widely used in railroad analysis. They are documented in an earlier report: *Impacts of Heavy Axle Loads on Light Density Lines in the State of Washington*, March 2001.[22] According to Hay (1982), the equations are "comprehensive" and "produce results very close to those observed in the field."[23]

Figure 1 illustrates track deflections for a hypothetical 90-pound rail section with ballast depths of 6 and 12 inches. As the graph shows, the simulated deflections are less than one-half inch with good tie maintenance (e.g., an effective spacing of 21 inches). However, with 50 percent defective ties, this track may deflect from .72 to .92 inches. The maximum deflection may exceed one inch with two-thirds defective ties and 6 inches of ballast.

Not much is known about the depth and quality of the ballast beneath the ties on the Coulee City line. It is likely that some thin ballast sections exist. Overall, 50 percent of the crossties are defective.[24] With variable and weak subgrade support and 50 percent bad ties, the 85-pound and 90-pound rail sections will experience excessive deflections that will result in track depressions, broken rails and joint bars, shortened tie lives, and many other problems.

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[19] At the time these guidelines were developed, AREMA was the American Railway Engineering Association. In this study, all references to this association use the current name. A key reference for the deflection guideline of 0.25 inches is: Report of the Committee on Economics and Construction Maintenance, *Proceedings of the American Railway Engineering Association*, 1974.

[20] The source of the deflection guideline is: J.R. Lundgren, et al., *A Simulation Model of Ballast Support and the Modulus of Track Elasticity*, Transportation Series Report 14, University of Illinois, 1970. The criteria are shown in Figure 15.8 of: William W. Hay. *Railroad Engineering*, 2nd Edition, John Wiley & Sons, 1982.

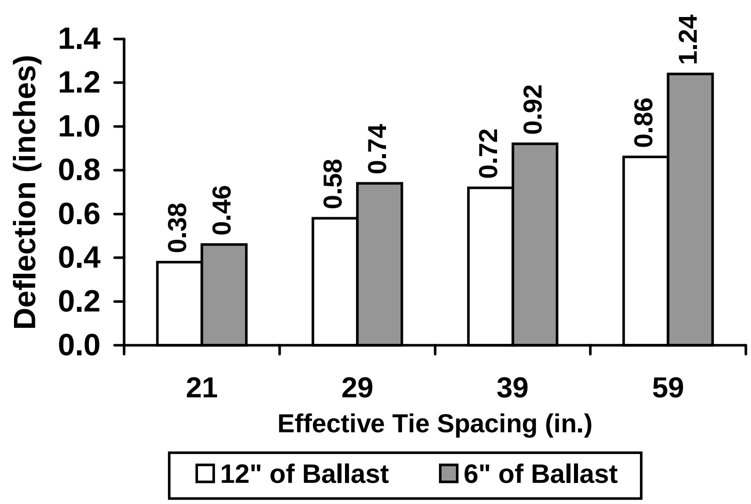
[21] The source of the deflection guideline is: J.R. Lundgren, et al., *A Simulation Model of Ballast Support and the Modulus of Track Elasticity*, Transportation Series Report 14, University of Illinois, 1970. The criteria are shown in Figure 15.8 of: William W. Hay. *Railroad Engineering*, 2nd Edition, John Wiley & Sons, 1982.

[22] Casavant, Ken and Denver Tolliver. *Impacts of Heavy Axle Loads on Light Density Lines in the State of Washington*, March 2001.

[23] Hay, William W. *Railroad Engineering*, 2nd Edition, John Wiley & Sons, 1982.

[24] Estimate of PCC general manager and former roadmaster, verified by spot tie counts.

Figure 1 Predicted Track Deflections for 90-Pound Rail with Varying Tie Spacing and Ballast Depths

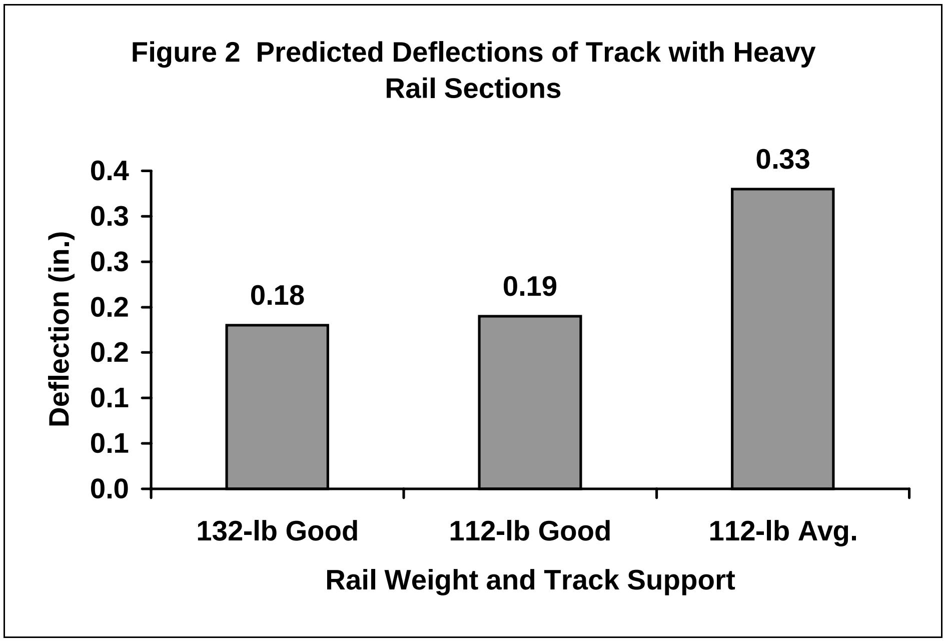


With 90-pound rail, track deflections under 286,000-pound car wheel loads exceed .5 inches with one-third defective ties and .7 inches with 50 percent defective ties at speeds of less than 40 mph.

Improved Performance of Heavy Rail

An important and related question is: How will heavier rail perform on a long-term basis under 286,000-pound car loads? As Figure 2 illustrates, 112-pound or 132-pound rail should provide excellent performance with good track support. The expected deflections are less than .25 inches for both rail weights. In addition, 112-pound rail performs reasonably well with only average track support.[25] These simulations suggest that it's desirable to upgrade the old 85-pound and 90-pound rail sections on the line with heavier rail.

[25] Scenario 1 reflects 22 inches of ballast while scenarios 2 and 3 reflect 16 inches. Effective tie spacing is 21 inches for scenarios 1 and 2 and 29 inches for scenario 3.



Track with 112-pound rail and average track support deflects only .33 inches under 286,000-pound car wheel loads at speeds less than 40 mph.

In summary, several studies have suggested that the light rails on the line should be replaced. From an analytical perspective, it is appropriate to consider these costs as rehabilitation instead of normalized maintenance. Approximately 80 miles of rails are approaching the ends of their useful lives at approximately the same time. Because of the magnitude of rail replacement, it is difficult to estimate a meaningful long-term maintenance cost with the light rails included.

Rehabilitation Cost

Two rehabilitation scenarios are analyzed in this study: (1) phased replacement of old light rails and (2) upfront replacement. Rehabilitation estimates for both scenarios are derived from detailed track data developed by Wilbur Smith Associates (WSA) in a previous study (Appendix E). Both estimates are based on a replacement cost of $200,000 per mile, which reflects the cost of laying 132-pound continuous welded rail (CWR).[26]

In phased renewal, it is assumed that approximately 8 miles of rails are replaced each year for the next ten years. This schedule results in an annual replacement cost of $1.61 million (Table 6). In the second scenario, all 80 miles are rehabilitated immediately at a lump-sum cost of $16.1 million.

[26] Depending on market conditions and rail availability, this unit cost could vary in the future thus changing the rehabilitation estimate.

Table 6. Annual Light Rail Replacement Needs of the Cheney-to-Coulee City Rail Line: Phased Rehabilitation	
Cheney-Davenport	$562,600
Davenport-Coulee City	$1,042,800
Total	$1,605,400
Source: Wilbur Smith Associates, 1999	

In the WSA study, a substantial amount of corrective work was identified to replace broken joint bars and missing anchors. If the line is rehabilitated immediately, corrective work will not be needed on these sections. However, joint and anchor replacement will be needed in phased rehabilitation. In this study, the corrective work is phased in over a 5-year period. The annualized cost of $443,000 envisions that joint work will not be needed on light rails that are replaced each year.

In summary, the annualized rehabilitation cost estimate is $2.05 million for the first five years and $1.61 million for the last five years of the period. With rail replacement cost considered separately, the normalized maintenance estimate includes ties, ballast, turnouts, crossings, bridges, and remaining track components.

Normalized Maintenance Cost Estimate

Table 7 summarizes the normal maintenance cost estimate for ties, ballast, and surfacing work developed by WSA (Appendix E).[27] Separate estimates are given for the Cheney-to-Davenport and the Davenport-to-Coulee City segments. Column 2 of Table 7 shows the cost estimate for each segment, the total estimate for the line, and the average cost per mile for the line as a whole. Column 3 of Table 7 presents cumulative or running totals.

As Table 7 shows, normal tie maintenance, track surfacing, and ballast renewal comprise the largest component of the estimate (approximately $5,400 per mile). When turnouts and switch ties are included, the cost estimate increases to approximately $6,900 per mile. Inclusion of culverts, ditches, and related work brings the cumulative maintenance cost to $7,600 per mile. Finally, with maintenance of grade crossings and bridges included, the normalized cost increases to $8,400 per mile.

[27] The PCC is spending approximately $4,000 per mile on track maintenance each year. This doesn't include rail replacement. A 5-year surfacing cycle is being practiced on the line. Since taking over the line in 1997, the PCC has surfaced 38 miles of line (spreading 50 to 60 carloads of ballast onto these sections) and replaced 20,000 crossties. Twelve hundred of the new crossties were laid between mileposts 3 and 40. These crossties are expected to last 50 to 55 years under the current light traffic loads. For the line as a whole, approximately 50 percent of the crossties are in good condition.

Table 7. Normalized Track Maintenance Estimate for the Cheney-to-Coulee City Rail Line Excluding Rail Replacement and Corrective Joint Work		
Ties, Ballast, & Surfacing	**Segment Cost and Cost per Mile**	**Cumulative Cost**
Cheney-Davenport	$243,135	
Davenport-Coulee City	$340,960	
Line Total	$584,094	$584,094
Cost per Mile	$5,408	$5,408
Turnouts & Switch Ties		
Cheney-Davenport	$36,450	
Davenport-Coulee City	$128,400	
Line Total	$164,850	$748,944
Cost per Mile	$1,526	$6,935
Culverts, Ditching, Cribbing		
Cheney-Davenport	$33,350	
Davenport-Coulee City	$35,910	
Line Total	$69,260	$818,204
Cost per Mile	$641	$7,576
Grade Crossings		
Cheney-Davenport	$26,150	
Davenport-Coulee City	$25,840	
Line Total	$51,990	$870,194
Cost per Mile	$481	$8,057
Bridges		
Cheney-Davenport	$10,616	
Davenport-Coulee City	$24,854	
Line Total	$35,470	$905,664
Cost per Mile	$328	$8,386
Source: Wilbur Smith Associates, 1999		

Table 7 excludes the cost of the 85-pound and 90-pound rail sections. These costs are accounted for in the rehabilitation expense. The 112-pound and 115-pound rail sections have estimated service lives of 50 to 100 years. These rails will last far beyond the time horizon of the analysis. Therefore, they are excluded from the normalized cost estimate. However, most of these sections (22.7 miles) are comprised of bolted rails. Thus, some maintenance of joint bars and bolts is necessary. An annualized estimate of $500 per mile is used for the approximately 23 miles of heavy bolted rail. This results in an additional cost of $11,350 or $105 per mile for the line as a whole.

The 6.88 miles of 100-pound bolted rail is estimated to have a remaining service life of 30 years (WSA). Technically, the life of this rail extends beyond the time horizon of the study. However, the estimated replacement date of this rail is close enough to the present that it is included in the normalized maintenance estimate. The annualized replacement cost of this rail is $45,867 (Appendix E). The inclusion of annualized rail and joint replacement expenses increases the normal maintenance cost to $962,880 or approximately $8,915 per mile.

AREMA Normalized Maintenance Factors

In 1994 AREMA developed a set of equated track maintenance factors for use in railway maintenance studies. These factors can be used to compare expected maintenance costs for various track designs. They are documented in the *Manual for Railway Engineering* (AREMA, 2000).

The equated track maintenance factors represent different types of track components, geometry, and traffic loads. The baseline track factors correspond to Federal Railroad Administration track speed classifications (Table F.1, Appendix F). A value of 1.0 or unity is assigned to Class 4 first-main tangent track with 20 to 25 million gross tons (MGT).

Analysis of Tangent Track Sections

In the AREMA procedure, track maintenance comparisons are made by totaling the individual track factors. The resulting numbers are in ratio form. The ratio is the comparative level of maintenance required for one type of track versus the reference track. For example, the equated maintenance factor for a Class 2 branch-line tangent track is .52 (Table F.1). This means that the annual maintenance cost of a branch-line track with a maximum train speed of 25 mph is 52 percent of the maintenance cost of a Class 4 mainline track. This ratio reflects the maintenance of a first-main track only. It doesn't include the maintenance of second main tracks, turnouts, grade crossings, and bridges.

In order to translate these ratios into dollars, a cost per mile must be estimated for the maintenance of Class 4 first-main track. A value of $12,000 was used in an AREMA illustration. However, this value is based on early 1990 costs. For this study, it is inflated to current levels using a weighted-average price index for labor and materials. The result is a current estimate of approximately $15,500 per mile for Class 4 first-main tangent track. Multiplying this reference value by .52 yields an estimate for Class 2 branch-line tangent track of approximately $8,000 per mile. However, this estimate must be adjusted for turnouts, crossings, curves, rail attributes, axle loads, and traffic density.

Table 8 shows the estimation of equated track factors for turnouts and grade crossings. In each row, a factor per mile (Column 3) is computed from the appropriate AREMA factor (Column 1) using the average turnout or crossing frequency per mile computed from track profile charts (Column 2). The sum of these factors (0.078 per mile) is added to the branch-line tangent track factor of .52 to yield an aggregate baseline factor of .60.

Table 8. Equated Class 2 Tangent Track Maintenance Factors for the Cheney-to-Coulee City Rail Line

	Factor for Each[1]	Frequency per Mile[2]	Factor per Mile[3]
Turnouts	0.050	0.460	0.023
Highway Grade Crossings			
Paved	0.090	0.185	0.017
Unpaved	0.050	0.463	0.023
Farm, Private, or Unimproved	0.020	0.759	0.015

Column Sources: (1) Appendix D, (2) Appendix D, (3) Column 1 x Column 2

In the next step of the procedure, the baseline track factor is adjusted for rail weight, axle loads, and traffic density (Table 9). These factors are derived from Tables F.2 and F.3 (Appendix F).

Table 9. Equated Class 2 Track Factors for Rail Weight and Traffic Characteristics of the Cheney-to-Coulee City Rail Line

Rail Weight Less Than 100 lb. per Yard	1.09
Axle Loads Greater Than 66 Kips	1.50
Traffic Density Less Than 5 MGT	0.50

The baseline factor of 0.6 is multiplied by the rail weight and traffic factors shown in Table 9. The result is an adjusted track maintenance factor of .49 and an equated cost per mile of approximately $7,600, excluding bridges. However, the preceding calculations reflect tangent track only. The line includes many curves, which must be considered.

Analysis of Bolted Curve Rails

As noted earlier, the line includes approximately 23 miles of bolted 100- to 115-pound rail in curves. Generally, track maintenance cost in curves is greater than in tangent track because of lateral forces. However, heavier rails usually are placed in curves. These countervailing forces must be considered in a track analysis.

The AREMA factors allow for adjustments based on curve severity. Four categories of curves are defined (Appendix E):

- Curves of less than 2 degrees
- Curves from 2 to 4 degrees
- Curves from 4 to 6 degrees
- Curves of more than 6 degrees

The Coulee City line is characterized by a diversity of curvature. Some curves are 8 degrees. Others are less than 4 degrees. Many others fall into the 4-to-6 degree category. To simplify the analysis, it is assumed that the typical curve is 4 degrees or greater.

Table 10 shows the calculation of an adjusted track maintenance factor for a 4 to 6 degree curve. When the curve factor is considered, the maintenance cost increases to $10,350 per mile for the jointed 100- to 115-pound rail sections.

Table 10. Equated Track Maintenance Factor for Jointed Curve Rail in the Cheney-to-Coulee City Rail Line

Baseline Factor, Class 2 Track	0.60
Rail Weight:100 to 115 lb. per yd.	1.05
Axle Loads (> 66 kips)	1.50
Curves: 4 degrees	1.42
Traffic Density of Less Than 5 MGT	0.50
Adjusted Track Factor, Class 2 Track	0.67

Analysis of Continuous-Welded Curve Rails

Approximately five miles of line are built with 112-pound or 115-pound continuous welded rail. The calculation of an adjusted track maintenance factor for these sections is shown in Table 11. Based on a curve track factor of 0.47, the estimated annual maintenance cost decreases to $7,190 per mile for the 112- to 115-pound CWR sections.

Table 11. Equated Class 2 Track Maintenance Factors for CWR Curve Rail in the Cheney-to-Coulee City Rail Line	
Baseline Factor, Class 2 Track	0.60
Rail Weight: 112 to 115 pounds per yard	1.05
CWR	0.70
Curves: 4-6 degrees	1.42
Axle Loads (> 66 kips)	1.50
Traffic Density of Less Than 5 MGT	0.50
Adjusted Track Factor, Class 2 Track	0.47

Weighted-Average Track Maintenance Cost per Mile

In the final step of the calculation, a weighted-average cost per mile is computed for tangent-bolted, curve-bolted, and curve-CWR track. The cost per mile, miles of line, and annual maintenance costs are summarized in Table 12. The inferred weighted-average cost is $8,153 per mile, excluding bridge maintenance.

Table 12. Estimated Maintenance Cost for Tangent and Curve Rail Sections in the Cheney-to-Coulee City Rail Line

Rail Section	Rail Type	Cost per Mile	Miles	Annual Cost
Tangent	Bolted	$7,568	81	$612,978
Curved	Bolted	$10,352	23	$238,089
Curved	CWR	$7,190	5	$35,950
Total			109	$887,017

As shown earlier in Table 7, the normalized bridge maintenance cost estimate from the WSA study is about $330 per mile. When these bridge costs are added to the weighted average computed from AREMA factors, the normalized maintenance cost increases to $8,483 per mile. In the final comparison, the difference between the AREMA and WSA maintenance-of-way cost estimates is less than $550 per mile. However, both of these estimates are based on the maintenance of 81 miles of bolted light rail.

Maintenance-of-Way Cost Estimate for Upgraded Track

As noted earlier, it is assumed that the light bolted rail sections with less than 10 years of remaining life are upgraded to heavy CWR sections—e.g., 132 pounds per yard. After rehabilitation, the equated track maintenance factor drops from 0.49 to 0.31 (Table 13). Consequently, the weighted-average cost drops to $6,137 per mile (Table 14). However, when bridge costs are added in, the normalized maintenance estimate increases to $6,467 per mile.

Table 13. Track Maintenance Factors for Upgraded Tangent Rail Sections of the Cheney-to-Coulee City Rail Line	
Base Track Factor for Class 2 Branch Line	0.60
CWR	0.70
Axle Loads (> 66 kips)	1.50
Traffic Density of Less Than 5 MGT	0.50
Adjusted Track Factor, Class 2 Track	0.31

Table 14. Estimated Maintenance Cost for Upgraded Track Sections of the Cheney-to-Coulee City Rail Line

Rail Section	Rail Type	Cost per Mile	Miles	Total Cost
Tangent	Bolted	$4,860	81	$393,656
Curved	Bolted	$10,352	23	$238,089
Curved	CWR	$7,190	5	$35,950
Totals			109	$667,694

In summary, the normalized track maintenance cost is roughly $175 per carload based on 2000 traffic levels. However, this estimate is only applicable to a rehabilitated track structure in which the old light rail is replaced upfront with heavy continuous welded rail. It is not applicable to phased rehabilitation. Moreover, the estimate assumes good tie and ballast maintenance and doesn't include corrective subgrade work or spot maintenance resulting from areas of poor track support. For these reasons, the estimate should be interpreted judiciously. In the final analysis, allowances or contingencies for subgrade and ballast problems may be needed.

Track Ownership Cost

Measurement Focus

There are several ways to estimate track ownership cost. In the classic accounting approach, a minimum acceptable return on investment is computed. Net investment is defined as original cost minus accumulated depreciation. However, when looking at a specific rail line, the net liquidation value (NLV) is often used.

NLV reflects the current value of the line based on market prices for individual assets—e.g., rails, ties, other track materials, and land. It is a net value that accounts for removal and restoration costs and transportation cost to the location where the asset will be used or scrapped.

Data Sources

The track asset values used in this study were provided by Wilbur Smith Associates. These estimates are based on detailed field surveys conducted in 1998 and 1999. The detailed calculations underlying the estimated net liquidation values are shown in Appendix G.

The quantities and descriptions of track materials have not changed appreciably since the field survey was conducted. The price of materials may vary from year-to-year and fluctuate based on market demand and scarcity. Even if the unit prices used in this analysis have increased materially during the last three years, the removal costs may have increased as well. Overall, the effects of any potential price increases may be dampened by increases in removal costs.

Net Liquidation Value

As shown in Table G.1 of Appendix G, the estimated track salvage value of the Cheney-to-Davenport segment is $1,475,500. However, the estimated removal cost of these assets is $565,900 (Table G.2, Appendix G). Thus, the net liquidation value (NLV) is approximately $909,600.

The estimated salvage value of track assets in the Cheney-to-Davenport segment of the line is $1,643,000 (Table G.3, Appendix G). However, the removal cost associated with these assets is $758,440 (Table G.4, Appendix G). Thus, the NLV of this segment is $884,560. The NLV for the entire line is approximately $1,794,150.

Opportunity Cost

The minimal rate of return depends on the opportunity cost of the track assets—i.e., their highest value when used for another purpose. An opportunity cost rate is difficult to define. It may vary with market conditions and type of asset.

The Surface Transportation Board (STB) computes a regulatory cost of capital for Class 1 railroads. The cost of capital is a benchmark for assessing revenue adequacy. In 2001 the railroad cost of capital was 10.2 percent. In the absence of specific knowledge about alternative uses of the capital invested in the Coulee City line, it seems reasonable to use the cost of capital as a proxy for the unknown opportunity cost rate. When the opportunity cost rate of .102 is applied to the NLV, the resulting annual cost is $183,003—roughly $46 per car.

The opportunity cost of land cannot be computed accurately at this time. There is some uncertainty regarding the title and whether the properties would revert to the state or to the previous owner. A reversionary clause would mean that there is no opportunity cost. Moreover, the net value of the land may be small if substantial recovery or reclamation work is needed to make the land appropriate for its alternative use. For example, if the alternative use is agriculture, the right of way must be graded and smoothed and some timbering work may be necessary. Moreover, transaction costs such as real estate fees must be subtracted from the value of the land. In the final analysis, the net liquidation value of the land may be small or negative.

Implications for Profitability

On-Branch Revenues and Costs

All facets of on-branch cost are summarized in Table 15 and compared to the revenue division for the branch-line operator. Altogether, train operating, car ownership, and clerical cost amount to $244 per car. The estimated branch-line maintenance cost is approximately $175 per car after rehabilitation, or $231 per car as is. The estimated track ownership cost (excluding land) is $46 per car. These estimates sum to $521 per car without rehabilitation. If the car-day costs are shifted to the off-branch portion of the movement, the on-branch cost drops to $446 per car. As noted earlier, the branch-line operator's current revenue division is $400 per car.

Table 16 summarizes the same information, assuming the line is rehabilitated. After rehabilitation, the normalized maintenance cost drops to $175 per car and a very small profit is forecast for the line. However, with all of the uncertainty in the estimates, it is perhaps more appropriate to say that the line represents a break-even proposition after rehabilitation. The small profit shown in Table 16 doesn't reflect rehabilitation costs, which must be added to the carload cost total. In phased rehabilitation, the cost responsibility for the first year of the period is $511 a car. Clearly, it is cost-prohibitive for a private railroad to make such an investment, given the revenue division.

Table 15. Estimated Revenues and Costs Without Rehabilitation of the Cheney-to-Coulee City Rail Line	
Cost Estimates per Car	
Train, Car Ownership, & Clerical	$244
Track Maintenance	$231
Track Ownership	$46
Total On-Branch	$521
Total, Excluding Car-Day Cost	$446
Revenue per Car	$400
Profit (Loss) per Car	$(46)

Table 15. Estimated Revenues and Costs With Rehabilitation of the Cheney-to-Coulee City Rail Line	
Cost Estimates per Car	
Train, Car Ownership, & Clerical	$244
Track Maintenance	$175
Track Ownership	$46
Total On-Branch	$465
Total, Excluding Car-Day Cost	$390
Revenue per Car	$400
Profit (Loss) per Car	$10

Total Movement Profitability

In the final phase of the viability analysis, the overall profitability of the wheat movements is re-examined in light of the on-branch costs. As shown earlier, the estimated variable cost for the Cheney-to-Portland movement in 286,000-pound cars is $573 per car (Table 1). In the current interline agreement, BNSF forgives the time-related portion of car-hire charges if the car is returned to Cheney within five days. This arrangement shifts the car-day responsibility to the off-branch portion of the movement. When these costs are included in the analysis, the variable off-branch cost increases to $648 per car and the fully allocated cost increases to $877 per car (Table 17).

Table 17. Comparison of Revenues and Total Movement Costs for the Cheney-to-Coulee City Rail Line	
Off-Branch Cost per Car	
Variable Cost	$573
On-Branch Car-day Cost	$75
Total Variable Cost	$648
Fully Allocated Cost	$877
On-Branch Cost per Car	$390
Total Variable Cost per Car	$1,038
Revenue per Car	$1,366
Variable Cost Margin	$328
Fully Allocated Cost Margin	$99

As noted earlier, the 26-car wheat rate to Portland is $1,366 per car when shippers use 286,000-pound cars. The total estimated on-branch and off-branch variable cost is $1,038 per car (Table 17). Thus, the margin of revenue over variable cost is $328 per car. However, when fully allocated off-branch cost is considered, the profit margin drops to $99 per car.

The implications of the profitability analysis are:[28]

- Even with 286,000-pound cars, the overall profit margin is slim for the wheat movements. This is not a surprising conclusion given the strong waterway competition in the region.
- Based on the current revenue division of $400 per car, the line is projected to incur a loss when normalized track maintenance and ownership costs are considered.
- After the line is rehabilitated, a small operating profit is possible. However, when debt service resulting from rehabilitation is considered, the annualized cost exceeds the revenue.

[28] This analysis considers current rail traffic only. It does not consider the potential effects of shipments currently moving by truck. Modest increases in rail traffic would have little or no impact on annual track maintenance and ownership costs. However, modest traffic increases would have a significant effect on profitability. For example, increasing the traffic density from 37 cars per mile to 55 cars per mile—i.e., from 4,000 to 6,000 annual carloads—would reduce the normalized track maintenance and ownership cost by $73 per car. Such economies of utilization would change the line's financial status from break-even to modestly profitable.

Potential Impacts of Ritzville Shuttle Train Facility

A 110-car shuttle train facility has opened at Ritzville. Shippers fear that this facility may impact the viability of the Coulee City line. The impacts of this facility will depend upon many factors. The pricing policy of the BNSF is certainly one of the most important variables.

As noted earlier, the 26-car rate from stations located on the Coulee City line to Portland is $1,366 per car for shipments in 286,000-pound cars. In comparison, the 26-car rate from Ritzville to Portland is $1,015 per car. Moreover, the rate for 110-car shipments from Ritzville to Portland is only $907 per car. In effect, the shuttle train rate results in a price differential of 12 cents a bushel for shippers located on the Coulee City line (Table 18).

Table 18. Comparison of Rates for Wheat Movements from Coulee City and Ritzville to the Pacific Coast in 286,000-Pound Rail Cars*

	Coulee City	Ritzville
Cars per Shipment	26	110
Rate per Car	$1,366	$907
Bushels per Car	3,700	3,700
Rate per Bushel	$0.37	$0.25

**This comparison is valid for all stations on the Coulee City Line.*

As shown in Table 19, the trucking cost for a wheat movement in a 7-axle Rocky Mountain Double is approximately $1.40 per mile. The Rocky Mountain Double cost is the lowest rate that shippers could expect to pay for transshipments to Ritzville.

The estimated trucking cost for the 91-mile trip from Coulee City to Ritzville is approximately 11 cents a bushel (Table 19). This estimate falls within a range of rate quotes provided by shippers. According to shippers, the truck rates from elevators on the Coulee City line to Ritzville range from 10 to 15 cents per bushel.[29] Thus, it appears that the combined truck-rail cost for shipments via Ritzville is about 36 cents a bushel. However, the additional transfer cost (i.e., the double-handling cost) is roughly five cents per bushel.

[29] This information is based on interviews with shippers located along the Coulee City line. These interviews were conduct by Mr. Ray Allred of WSDOT. The findings of the interviews are described in an internal memo dated September 2, 2001.

Table 19. Trucking Cost for Wheat Shipments from Coulee City to Ritzville in Rocky Mountain Doubles	
Cost Factor	**Value**
Truck Cost per Mile*	$1.40
Trip Distance	91
Cost per Round Trip	$127
Bushels per Trip	1,200
Cost per Bushel	$0.11
**Robert Holmes, Whitman County Grain Growers*	

The cost comparison suggests that the elevators located on the Coulee City line should continue to use it. However, this comparison doesn't consider Certificate of Transportation (COT) premiums that branch-line shippers may have to pay for guaranteed rail car supply. The COT premiums are market-driven and may range from zero to $300 per car. A high COT premium could shift the advantage to Ritzville.

Post-Abandonment Decision Factors

Chapter 2 of this report is concerned with the potential highway impacts of abandonment. If the PCC rail lines are abandoned, the traffic currently moving by rail will be moved by truck to a final market, a rail mainline station, or a barge transfer facility. The destinations and trip distances of the post-abandonment movements will determine the magnitude of the increased highway costs. Moreover, the distribution of traffic after abandonment will affect the total transportation cost incurred by shippers.

The trip distance from Coulee City to Portland is about 350 miles. Thus, it is unlikely that grain will move directly by truck to final market. Instead, it will be trucked to a rail mainline station (e.g., Ritzville) or barge transfer facility. Many variables will affect an elevator's post-abandonment shipping decisions. Most of these decision variables can be classified as service, cost, or institutional factors.

Service and Institutional Factors

Institutional factors include joint ownership or financial integration of elevator and port facilities. These factors are important. However, they are difficult to quantify. Service factors include:

- Total shipment transit time
- Variability in shipment transit time
- Equipment availability
- Carrier responsiveness and customer service

Tidewater Barge Lines advertises 36-hour transit times from Tri-Cities to Portland. Grain can be trucked from elevators on the Coulee City line to Tri-Cities in a matter of hours. If these reported transit times are consistent, then the time consumed during a truck-barge shipment may be 48 hours or less. This speed compares favorably with an estimated rail transit time of more than five days (Table 20). In actuality, rail transit times may be greater than the average shown in Table 20, especially if a car spends longer than one half-day in Cheney or congestion is encountered in the Vancouver-Portland area.

Capacity and availability of equipment are other important decision factors. If car supply isn't reliable or car-order cycles are lengthy, shippers may perceive that rail service is less reliable than truck-barge service. Finally, response time is important to shippers. In some instances, shippers may realize premiums in the export market if they can assemble and deliver a shipment of grain on short notice. These market factors tend to favor the truck-barge mode.

Table 20. Loaded Rail Car Transit Time for Grain Originated from the Cheney-to-Coulee City Rail Line

Activity or Event	Days per Event
On-Branch Activities	3.0
Interchange at Cheney	0.5
Road Train Movement	0.7
Intertrain Switch at Pasco	0.5
Switching and Delivery	0.5
Total Loaded Car-Days	5.2

Cost Factors

Cost factors are easier to quantify than service and institutional factors. Moreover, if one mode has a clear advantage over others, cost may be the overriding decision factor.

In this section of the chapter, a comparative analysis is presented. Combined truck-barge and truck-rail shipment costs are estimated for elevators located on the Coulee City line in a post-abandonment scenario.

Truck-Rail Unit Train Cost

Table 21 shows an estimate of the total cost of shipping wheat from Coulee City to Portland via Ritzville. In this scenario, the shipment cost consists of three elements:

- The trucking cost from Coulee City to Ritzville;
- The transfer or double-handling cost at Ritzville; and
- The rail rate from Ritzville to Portland.

In this comparison, all costs are converted to a cost per ton. As shown in Table 21, the trucking cost from Coulee City to Ritzville in a Rocky Mountain Double is $3.54 per ton. The 110-car unit train rate from Ritzville to Portland is $8.17 per ton. Thus, the total shipment cost (including double-handling cost) is $13.38 per ton.

Truck-Barge Cost

The barge rate for grain shipments from Pasco to Portland is $5.53 per ton (Table 22). However, it is 116 highway miles from Coulee City to the Port of Pasco. For this distance, the round-trip trucking cost is $9.02 per ton. Thus, when total shipment costs are considered, the truck-barge cost is approximately $2.84 more per ton than the truck-unit train cost.

Table 21. Total Shipping Cost for Wheat Movements from Coulee City to Portland via Ritzville

Cost or Rate Factor	Value
Truck Cost per Mile	$1.40
Trip Distance	91
Cost per Round Trip	$127
Net Tons per Truck	36
Truck Cost per Ton	$3.54
Transfer Cost per Ton	$1.67
Rail Rate per Car	$907
Rail Rate per Ton	$8.17
Shipment Cost per Ton	$13.38

Table 22. Total Shipping Cost for Wheat Movements from Coulee City to Portland via Pasco	
Cost or Rate Factor	**Value**
Truck Cost per Mile	$1.40
Trip Distance	116
Cost per Round Trip	$325
Net Tons per Truck	36
Truck Cost per Ton	$9.02
Transfer Cost per Ton	$1.67
Barge Rate: Pasco-to-Portland	$5.53
Shipment Cost per Ton	$16.22

Truck-Rail Multiple Car Cost

The distance from Coulee City to the Tri-Cities makes truck-barge cost look unattractive in comparison to truck-unit train cost. However, there may be other transshipment options that are cost-competitive with Ritzville.

Odessa Union Warehouse Cooperative operates 26-car elevators in Ephrata and Odessa. The Odessa facility has 1.9 million bushels of storage capacity while the Ephrata facility can store 1.4 million bushels. Both of these stations are located on the Spokane-to-Everett mainline. Both stations lie directly south of elevators located on the Coulee City line. It is approximately 29 highway miles from Coulee City to Ephrata via US-2, SR-17, and SR-28 (Appendix A). The distance from Almira to Odessa is 38 miles via US-2 and SR-21. Finally, it is a 37-mile trip from Davenport to Odessa via SR-28.

Odessa is used as the transshipment point in this example because it is the closest mainline station to most of the elevators on the Coulee City line. Almira is selected as the origin because it is a weighted-center of branch-line traffic. As Table 23 shows, the total shipping cost from Almira to Odessa is 31 cents per ton more than the shipping cost via Ritzville. This cost differential amounts to a penny a bushel, which may not be a significant difference. However, the comparison suggests that there isn't a lower-cost transshipment option for elevators located on the Coulee City. Thus, transshipment via Ritzville is one of the scenarios that is considered in the abandonment impact analysis presented in Chapter 2 of this report.

Table 23. Total Shipping Cost for Wheat Movements from Almira to Portland via Odessa	
Cost or Rate Factor	**Value**
Truck Cost per Mile	$1.40
Trip Distance	38
Cost per Round Trip	$53
Net Tons per Truck	35
Truck Cost per Ton	$1.52
Transfer Cost per Ton	$1.67
26-Car Rail Rate per Car	$1,258
Rail Rate per Ton	$11.33
Total Shipment Cost per Ton	$14.52

As suggested by the previous analysis, abandonment of the Coulee City rail line would increase the total transportation cost incurred by shippers. If grain flows to the Ritzville facility after abandonment, the increased shipping costs will be minimized. However, much of the grain is likely to move to river ports. Abandonment of the Coulee City line will have no appreciable impact on the viability of railroad mainlines in eastern Washington. Much of the traffic moving over the BNSF and UP mainlines consists of through or overhead traffic that neither originates nor terminates in eastern Washington.

Analysis of the Marshall-to-Pullman Line

The analytical methods and data used in this study were detailed and illustrated for the Coulee City line. With few exceptions, the same techniques and data sources are used for the Marshall-to-Pullman line and the remaining lines of the PCC.

Traffic and Train Operations

Approximately 1,950 carloads were originated or terminated on the Marshall-to-Pullman line in 2000. Most of these cars were loaded with wheat or barley. A few carloads of lentils, peas, beans, and seeds are originated each year and some inbound carloads of farm chemicals are moved to Palouse and Oaksdale. Some forest products traffic is originated on the WIM subdivision in Idaho.

The Marshall Line connects with the Hooper Junction line at Pullman. Train operations are segmented on this part of the railroad. Typically, a train operates from Marshall to Pullman. Another train operates from Hooper Junction through Pullman to Moscow. Any traffic interchanged at Marshall that is destined for Moscow is setout at Pullman for the Hooper Junction-to-Moscow train to pick-up and haul into Moscow.

Currently all grain originated from Whelan to Spangle moves north to Marshall for interchange with BNSF. Because of the physical connection at Pullman, it is feasible to move grain originated south of Rosalia (e.g., at Fallon) to Hooper Junction. However, the BNSF owns and provides all of the freight cars used on this line.[30]

The track is rated at FRA Class 2, which allows a maximum train speed of 25 mph. The locomotives are rated at 2,000 to 2,500 horsepower each. Given the grade and direction of the loaded movements, a maximum of 40 loaded cars can be pulled by two locomotive units.[31] In this analysis, the average train is assumed to consist of 30 cars pulled by two locomotives.[32]

On-Branch Train and Car Costs

Based on the train factors described previously, the estimated train and car costs for the Marshall-to-Pullman line are $79 per car (Table 24). As noted earlier, the regional average car ownership costs for a covered hopper car are 5 cents per mile and $15.07 per day.[33] The car-day running cost equals 38 percent of the total train and car cost (Table 24).

[30] Presumably, BNSF expects their cars to be interchanged with them at Marshall.
31 A maximum of 60 cars can be pulled by three units.
32 Assuming that the spotted-to-pulled ratio is 2.0, approximately 3,900 loaded and empty cars were moved over the line in 2000. A minimum of twice-a-week service is assumed, with a third train added as needed. If 130 trains move over the line each year, a train will consist of 30 cars, on average. If the cars are loaded, two 2,000 to 2,500 horsepower locomotives will be needed per train.
33 A few inbound farm machinery shipments move on flatcars and a few inbound farm chemical shipments move in tank cars. The car-day cost of a general service flatcar is higher than the car-day cost of a covered hopper car. However, tank cars are typically owned by shippers and have very low or zero car-day costs. Thus, the covered hopper car unit costs should be representative of the median car ownership costs of traffic on this line.

Table 24. Estimated Train and Car Running Costs Incurred on the Marshall-to-Pullman Rail Line			
Line	**Cost Factor**	**Source**	**Value**
1	Unit Cost per Gross Ton-Mile	E1P1	$0.00075
2	Average Gross Trailing Tons	Computed	1,928
3	Gross Ton-Mile Cost per Train-Mile	L1xL2	$1.45
4	Unit Cost per Locomotive-Mile	E1P1	$2.84
5	Avg. Locomotives per Train	Computed	2
6	Locomotive Cost per Train-Mile	L4xL5	$5.68
7	Crew Cost per Train-Mile	E1P1	$6.81
8	Other Train-Mile Unit Cost	E1P1	$0.59
9	Total Cost per Train-Mile	L3+L6+L7+L8	$14.54
10	One-Way Trip Distance	Assumed	76
11	Train Running Cost per Round Trip	L9xL10x2	$2,210
12	Unit Cost per Car Mile Running	E1P2	$0.050
13	Car-Mile Cost per Car per Round Trip	50xL12x2	$5
14	Car-Days Running per Round Trip	Assumed	2
15	Car-Day Unit Cost	E1P2	$15.07
16	Car-Day Cost per Car- Running	L14xL15	$30.13
17	Train & Car Running Cost per Car	L11/50+L13+L16	$79.30

Table 24 does not include on-line switching and terminal costs. The traffic on the Marshall-to-Pullman line is a mixture of single-car and 26-car shipments. The average regional switching time of 6.4 minutes per car is probably representative of mixed single-car and small multi-car shipments. Based on this switching factor, the estimated terminal and switching costs are $89 per car.

As shown earlier, the average interchange switching cost is $34 per car. When terminal, interchange, and switching costs are included, the total on-branch cost amounts to $202 per car. However, $75 of this cost is the car-day cost which is internalized by BNSF. If the on-branch car-day costs are allocated to BNSF, the PCC's cost drops to $127 per car.

Track Maintenance Cost

The AREMA track maintenance factors described earlier are used to estimate annualized maintenance costs based on the attributes of materials in the Marshall-to-Pullman line. Approximately 34 miles of 112-pound continuous welded rails are included in this line (Table 25). The line includes another 13 miles of 112-pound bolted rails. Only 23 percent of the rail is lighter than 100 pounds per yard. The line averages .81 paved public crossings, .83 unpaved private crossings, and .53 mainline turnouts per mile.

Table 25. Summary of Rail Weights in the Marshall-to-Pullman Rail Line			
Rail Weight (Lb per Yd)	**Rail Type**	**Miles**	**Percent of Miles**
85	Jointed	6.59	9
90	Jointed	10.75	14
100	Jointed	8.68	11
112	Jointed	13.06	17
112	CWR	34.28	45
115	Jointed	1.24	2
115	CWR	1.16	2
132	Jointed	0.02	0
Line Totals		75.78	100

Table 26 shows the estimated normal maintenance of way cost for the types and weights of rails found in the Marshall-to-Pullman line. These costs are computed from the AREMA factors shown in Appendix F. They reflect the frequencies of crossings and turnouts described above. However, they do not include bridge maintenance costs. Moreover, these costs are applicable to tangent track only.

Table 26. Estimated Normal Track Maintenance Costs per Mile for Tangent Rail in the Marshall-to-Pullman Rail Line		
Rail Weight	**Rail Type**	**Cost per Mile**
85	Jointed	$8,049
90	Jointed	$8,049
100	Jointed	$7,753
112	Jointed	$7,753
112	CWR	$5,427
115	Jointed	$7,753
115	CWR	$5,427
132	Jointed	$7,384

Table 27 shows normal track maintenance costs for the types and weights of rails found in the Marshall-to-Pullman line for various degrees of curvature. In most cases, heavier rails are laid in curves. Some curve rail is CWR. For the most part, the 112-pound and 115-pound rows of Table 26 are applicable to this analysis.

As the table shows, the estimated normal maintenance-of-way (NMOW) cost is $11,000 per mile for 112-pound bolted curve rails in 4 to 6 degree curves. For curves greater than 6 degrees, this cost increases to $15,660 per year. However, NMOW costs are much lower for 112-pound CWR for the same severities of curvature.

Table 27. Estimated Normal Track Maintenance Costs per Mile for Classes of Curve Rail in the Marshall-to-Pullman Line					
Rail Weight	**Rail Type**	**Degree of Curvature**			
		0 to 2	**2 to 4**	**4 to 6**	**> 6**
85	Jointed	$8,290	$9,819	$11,429	$16,258
90	Jointed	$8,290	$9,819	$11,429	$16,258
100	Jointed	$7,986	$9,459	$11,009	$15,660
112	Jointed	$7,986	$9,459	$11,009	$15,660
112	CWR	$5,590	$6,621	$7,707	$10,963
115	Jointed	$7,986	$9,459	$11,009	$15,660
115	CWR	$5,590	$6,621	$7,707	$10,963
132	Jointed	$5,324	$6,306	$7,340	$10,441

Approximately half of the track miles of this line are curved.[34] About half of the curve miles fall into the 2 to 4 degree category. Another 25 to 30 percent fall into the 4 to 6 degree class. Based on these distributions, a weighted track maintenance cost of $7,800 per mile is estimated for this line. As noted earlier, this estimate does not include bridge maintenance or costs associated with non-track assets. The types and frequencies of bridges on this line are similar to the bridge population of the Coulee City line. Thus, a normalized bridge maintenance cost of $300 to $400 per mile is probably applicable to this line.

The estimated normal maintenance cost of $7,800 per mile assumes the track is already on a schedule of normalized maintenance. Although the PCC is spending an average of $4,000 per mile, some corrective tie, ballast, and surface work may be needed before the normalized cost estimate is valid. In some areas of the line, the tie population is 30 to 50 percent defective. If corrective work is included in the normalized maintenance estimate for a 5- to10-year period, the annualized cost may increase substantially.

[34] The percentages of tangent and curved track and the percentage of curves in various severity classes were computed from track profile charts.

Track Ownership Cost and Financial Viability

Only track assets are considered in this analysis. As shown in Appendix G:

- The estimated salvage value of track assets in the Marshall-to-Moscow Line is $4,967,475 (Table G.5, Appendix G).
- The estimated removal cost of these assets is $1,322,960 (Table G.6, Appendix G).
- The estimated net liquation value is $3,644,515.

Approximately $225,000 of this NLV is attributable to the Pullman-to-Moscow segment. The estimated NLV of the Marshall-to-Pullman line is $3,419,500. The annual opportunity cost of these assets is approximately $403,500 or $207 per car. In addition, the annualized track maintenance cost is $304 per car. Collectively, these annual costs exceed the revenue per car generated from the line. When the train operating and terminal cost of $127 per car is considered, the conclusion is clear: the line is not viable as a private entity.[35]

Analysis of BLMR North

On-Branch Train and Car Costs

The BLMR North includes the Winona-to-Thornton branch as well as the Hooper Junction-to-Moscow line. Generally, four locomotives are required to serve this division. Some of the units are used to work the Thornton branch while others run to Pullman. On average, a train on the BLMR North is comprised of three locomotives and 53 cars. However, longer trains may be run between Hooper Junction and Winona and shorter trains may be run elsewhere on the system.[36]

Based on these operational factors, the estimated train and car costs for the BLMR North are $104 per car (Table 28). As shown in Table 28, the car-day running costs comprise 43 percent of this total.[37]

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[35] This analysis allocates the cars and revenues generated from the WIM subdivision to the line without adding in the track maintenance and ownership costs. Without the WIM traffic, the density on the Marshall-Pullman line would drop to 17 cars per mile and the financial picture would be much bleaker.

[36] Assuming that the spotted-to-pulled ratio is 2.0, approximately 6,900 loaded and empty cars were moved over the line in 2000. A minimum of twice-a-week service is assumed, with a third train added as needed. If 130 trains move over the line each year, a train will consist of 53 cars, on average. If the cars are loaded, three 2,000- to 2,500-horsepower locomotives will be needed per train.

[37] The UP allows five free car days. Because of the more complex train operations and the long-round trip distance to Moscow, an average of three car-days running is assumed per round trip. This results in a total of five on-branch car-days per car.

Table 28. Estimated Train and Car Running Costs Incurred on the Northern BLMR Lines			
Line	**Cost Factor**	**Source**	**Value**
1	Unit Cost per Gross Ton-Mile	E1P1	$0.00075
2	Average Gross Trailing Tons	Computed	4,025
3	Gross Ton-Mile Cost per Train-Mile	L1xL2	$3.04
4	Unit Cost per Locomotive-Mile	E1P1	$2.84
5	Avg. Locomotives per Train	Computed	3
6	Locomotive Cost per Train-Mile	L4xL5	$8.52
7	Crew Cost per Train-Mile	E1P1	$6.81
8	Other Train-Mile Unit Cost	E1P1	$0.59
9	Total Cost per Train-Mile	L3+L6+L7+L8	$8.96
10	One-Way Trip Distance	Assumed	70
11	Train Running Cost per Round Trip	L9xL10x2	$2,655
12	Unit Cost per Car Mile- Running	E1P2	$0.050
13	Car-Mile Cost per Car per Round Trip	55xL12x2	$5.46
14	Car-Days Running per Round Trip	Assumed	3
15	Car-Day Unit Cost	E1P2	$15.07
16	Car-Day Cost per Car- Running	L14xL15	$45.20
17	Train & Car Running Cost per Car	L9+L13+L16	$103.76

Table 28 does not include on-line switching and terminal costs. The traffic on the BLMR is a mixture of single-car and 26-car shipments. The average regional switching time of 6.4 minutes per car is probably representative of the mixed traffic. Based on this switching factor, the estimated terminal and switching costs are $89 per car.

When terminal, interchange, and switching costs are considered, the total on-branch cost comes to $227 per car. However, $90 of this total is the car-day cost which is internalized by UP. When the on-branch car-day cost is allocated to UP, the PCC's cost drops to $136 per car.

Co-Loading Rates

The UP recently introduced a new 75-car co-loading rate for grain traffic interchanged at Hooper Junction. This rate is designed to meet competitive threats from the new Ritzville shuttle-train elevator. The per-car rate for a 75-car co-loaded train originated on the BLMR North and destined for the Pacific Coast is $839 car. This rate is applicable to shipments in 263,000-pound rail cars.

The co-loading rates may improve operational efficiency on the BLMR by coordinating 25-car blocks originated from different stations. Moreover, these rates may encourage elevators to ship more 25-car blocks instead of individual cars.

Of the $839 per car, UP shares $214 with the BLMR. In addition, to the $214 in revenue division, BLMR assesses the following surcharges per car: $60 from Endicott; $120 from Saint John; and $180 from Thornton. At the highest surcharge level, BLMR receives less than $400 per car for this traffic.

Track Maintenance Cost

The AREMA equated track maintenance factors described earlier are used to estimate annualized maintenance costs for the BLMR North based on track attributes and materials. Table 29 summarizes information about the BLMR North lines. The Hooper Junction-to-Winona segment includes 7.2 miles of 133-pound rail. Overall, 27 percent of the rail in this segment is 110 pounds or heavier. However, the percentages are much lower for other segments, especially for the Colfax-to-Pullman and Winona-to-St. John segments.

Table 29. Summary of Track Characteristics: BLMR North

Segment	Percent Heavy Rail	Defective Ties per Mile	Percent Curves 6° or >
Hooper Jct. to Winona	27.0	437	8.4
Winona to Colfax	17.6	485	7.7
Colfax to Pullman	4.9	663	34.2
Winona to St. John	6.2	208	4.2
St. John to Thornton	18.9	204	7.8

Source: Wilbur Smith Associates, 1999

The defective tie counts are less than 25 percent assuming 2,800 ties per mile. However, some segments have substantial curvature. For example, 34 percent of the curves in the Colfax-to-Pullman segment are at least 6 degrees.

Table 30 shows the frequencies of paved public crossings, unpaved private crossings, and mainline turnouts per mile. The frequencies of private crossings and turnouts are relatively high for these segments.

Table 30. Average Road Crossings and Mainline Turnouts per Mile: Northern BLMR Lines			
	Road Crossings		
Segment	Paved Public	Unpaved Private	Mainline Turnouts
Hooper Jct. to Winona	0.26	0.56	0.67
Winona to Colfax	0.54	1.00	0.65
Colfax to Pullman	0.68	1.05	0.63
Winona to St. John	0.68	1.11	0.58
St. John to Thornton	0.39	1.01	0.47

Table 31 shows the estimated normal track maintenance costs for the BLMR North lines. The average (weighted by miles) is approximately $7,800 per mile.[38] These estimates assume that the track is already on a schedule of normalized maintenance. Although the PCC is spending an average of $4,000 per mile, some corrective tie, ballast, and surface work may be needed before the normalized cost estimate is valid. If corrective work is internalized in the normalized maintenance estimate for a 5- to 10-year period, the annualized cost may increase substantially.

Table 31. Estimated Annual Track Maintenance Cost of Northern BLMR Lines	
Segment	Normal Track Maintenance Cost per Mile
Hooper Jct. to Winona	$7,130
Winona to Colfax	$7,770
Colfax to Pullman	$8,498
Winona to St. John	$7,976
St. John to Thornton	$7,597

Track Ownership Cost and Financial Viability

The estimated track salvage values and removal costs are shown in Tables G.7 through G.16 of Appendix G. The results are also summarized in Table 32.

[38] The estimate total NMOW for all BLMR lines is $804,200.

As Table 32 shows, the estimated NLV for the BLMR North is $2,979,519. The annual opportunity cost of these track assets is approximately $351,580 or $102 per car. In addition, the annualized track maintenance cost is $233 per car. When the on-branch train and terminal costs of $136 per car are considered, the annual cost per car increases to $471. Even with surcharges, the average revenue for the 75-car trains is about $400 per car. Based on current rates and revenue divisions, this line does not appear to be viable in the long run as a private entity.

Table 32. Summary of Net Liquation Values of Northern BLMR Lines

Segment	Net Liquation Value
Hooper Jct. to Winona	$1,134,139
Winona to Colfax	$824,329
Colfax to Pullman	$315,785
Winona to St. John	$218,536
St. John to Thornton	$486,730
Total NLV	**$2,979,519**

Analysis of BLMR South

BLMR connects with the UP at Zanger Junction. From Zanger Junction, the BLMR line extends 27.5 miles to Walla Walla. From Walla Walla, the line extends another 38 miles to Dayton. A branch runs approximately 10 miles from Walla Walla to Milton Freewater, Oregon. In addition, BLMR operates over four miles of UP track from Zanger Junction to Wallula via trackage rights.

Traffic Density and Rail Weight

In 2000 the southern BLMR lines generated 1,336 carloads. The traffic density of these lines is 20 cars per mile or less. The low traffic density will make it difficult to sustain these lines under private ownership.

The Zanger Junction-to-Walla Walla line includes nearly 16 miles of 133-pound and 131-pound rails. Another 10.5 miles of this line consist of 110-pound and 112-pound rails. The remaining segments are built with light rail. Moreover, the Walla Walla-to-Dayton segment is all light rail consisting primarily of 85-pound, 80-pound, and 75-pound rails. Because of the light rails, car weights on the southern BLMR lines are restricted to 263,000 pounds.

Detailed track worksheets provided by Wilbur Smith Associates are shown in Appendix E. As the worksheets show, the remaining service lives of the light rails in the Walla Walla-to-Dayton segment are less than 10 years. These light rails will need to be replaced in the near future. The annualized replacement cost of these rails is over $1 million.

The annualized replacement cost of the light rail amounts to $750 per carload. This annualized cost doesn't consider other maintenance expenses on the Walla Walla-to-Dayton segment, normal maintenance of the Zanger Junction-to-Walla Walla and Walla Walla-to-Milton Freewater segments, or train operating and car ownership costs incurred in originating and terminating traffic on these lines. The estimated NMOW for the Zanger Junction-to-Walla Walla segment is $7,300 per mile. This segment has heavier rail, but it is all bolted rail. About half of the track miles are curves.

Although the salvage value of assets in the Walla Walla-to-Dayton segment is minimal, a substantial opportunity cost exists for the Zanger Junction-to-Walla Walla segment. As shown in Appendix G, the estimated net liquidation value of this segment is $1.44 million. The annual opportunity cost of the track assets is $170,000 or $127 per car.

Collectively, the annualized cost of light-rail replacement, normal maintenance of the Zanger Junction-to-Walla Walla segment, and the opportunity cost of track assets in the Zanger Junction-to-Walla Walla portion of the line exceed $1,000 per carload. This estimate includes only part of the fixed costs of the rail network and none of the train operating and car ownership costs. Clearly, the BLMR South is not viable in the long run as a private entity. Substantial track expenditures will be needed if these lines are to remain in service.

Conclusion

The PCC rail lines are a valuable part of the Washington State transportation system. The lines serve important grain producing regions and provide service to food and forest products industries. However, the future of these lines is uncertain. Because of low traffic densities, fixed and line-related costs comprise a large component of the PCC's annual expenses. Based on current revenue divisions, the lines are projected to incur losses as private entities when normalized track maintenance and ownership costs are considered.

Excluding the Walla Walla-to-Dayton branch, the net liquidation value of track assets located in PCC rail lines in Washington State is $9.86 million. The annual opportunity cost associated with these assets is $1.16 million or $109 per carload. The average track NLV is $30,600 per mile. The Zanger Junction-to-Walla Walla line is owned by UP. If this segment is excluded from the calculation, the average track NLV drops to $28,600 per mile. However, this NLV estimate does not include the opportunity cost of land.

Table 33. Summary of Track Net Liquidation Values of PCC Rail Lines

Segment	Miles	Net Liquation Value	NLV per Mile
Hooper Jct. to Winona	26.75	$1,134,139	$42,398
Winona to Colfax	26.10	$824,329	$31,583
Winona to St. John	19.00	$218,536	$11,502
St. John to Thornton	12.85	$486,730	$37,878
Colfax to Pullman	19.00	$315,785	$16,620
Marshall to Moscow	83.05	$3,644,512	$43,883
Cheney to Coulee City	107.46	$1,794,110	$16,696
Zangar Jct. to Walla Walla	27.50	$1,438,950	$52,325
Total	**321.71**	**$9,857,092**	**$30,640**

Excluding the Walla Walla-to-Dayton branch, the normal track maintenance cost of the PCC's lines located in Washington State is $7,900 per mile. Approximately 29 carloads are originated or terminated per mile on these lines. Thus, the normal track maintenance and annual opportunity costs equal at least $400 per car.[39]

If these lines cannot be operated profitably as a private entity, the state may be faced with a difficult choice—acquire the lines or let them be abandoned. Several in-between options may be possible. For example, the state could rehabilitate portions of the network for a private operator and/or assume part of the long-term maintenance cost. If the lines are rehabilitated, many benefits will be realized including highway cost savings. The normalized maintenance cost will drop each year. Shippers will save the trucking and double-handling costs associated with transshipments.

[39] This value excludes normal track maintenance of the Walla Walla-to-Dayton segment and rehabilitation costs and corrective maintenance associated with all PCC lines. When these costs are added in, the fixed costs per car are much greater than $400.

Chapter 2: Implications of Rail-line Abandonment for Pavement Preservation in Eastern Washington

Introduction

The Palouse River and Coulee City Railroad (PCC) operates 372 miles of light-density lines in eastern Washington. In 2000 these lines generated 10,700 carloads of traffic. Most of these carloads were shipments of grain destined for Columbia River ports.

The PCC has raised the possibility that these rail lines may be targeted for abandonment in the next five years. The company believes that the lines do not generate enough revenue to cover annual debt service and fund track and bridge rehabilitation needs. The PCC has offered to sell its lines to the Washington State Department of Transportation (WSDOT) for their net liquidation value.

The *Eastern Washington Grain-Hauling Short-Line Rail* is intended to analyze the viability of the PCC system as a private entity and identify the public benefits of preserving rail service on these lines. One of the primary benefits of preserving rail service is the avoidance of increased highway costs resulting from additional truck traffic on low-volume roads.

Rail lines subject to future abandonment

The PCC was created from a series of line sales by the Burlington Northern and Santa Fe Railway (BNSF) and the Union Pacific Railroad (UP). The PCC network consists of fours sets of lines or subsystems:

1. The Cheney-to-Coulee City line
2. The Marshall-to-Pullman line
3. The Blue Mountain Railroad − North
4. The Blue Mountain Railroad − South

The Coulee City line is 108 miles in length. It is also known as the Central Washington (CW) Branch. The Marshall-to-Pullman line is 76 miles long. It is part of the old Palouse and Lewiston (P&L) line. A branch of this line, known as the Washington, Idaho, and Montana (WI&M), extends eastward from Palouse, a distance of 47 miles, into Bovill, Idaho. The northern division of the Blue Mountain Railroad (BLMR) runs from Hooper Junction through Winona and Colfax to Moscow, Idaho.[1] A short branch of this line runs northeast from Winona

[1]The segment of the former Union Pacific line that ran from Pullman to Moscow has been abandoned. The PCC currently provides service between Pullman and Moscow over former BNSF tracks that were included in the P&L line sale.

to Thornton, a distance of 31 miles. The southern division of the Blue Mountain Railroad extends from the UP mainline at Wallula Junction to Walla Walla, where it connects with another line running from Dayton, Washington to Weston, Oregon.

Highways subject to potential increases in truck traffic

In this chapter, potential highway impacts are estimated for each of the four railroad subsystems and for the PCC as a whole. As many as 645 miles of highway in eastern Washington will be impacted if these rail lines are abandoned (Table 1).[2] About 355 of these miles (or 55 percent) are asphalt-concrete pavements. Another 272 miles (or 42 percent) consist of bituminous surface treatments. The remaining 18 miles (or 3 percent) are Portland Cement Concrete pavements.

Table 1. State Highways Potentially Impacted by PCC System Abandonment

Route	Miles
21	92
17	89
195	74
12	58
124	45
395	38
28	37
2	35
26	29
231	28
90	25
272	17
127	17
23	17
27	16
270	9
263	9
271	9
182	1
All	**645**

[2]This value corresponds to the miles of highway impacted by movements to river ports. If grain traffic is trucked to Ritzville after abandonment, the total number of highway miles impacted will be less.

More than 300 miles of rural minor arterial and collector highway are reflected in the mileages shown in Table 1. Most of these impacted segments are included in State Routes 17, 21, 27, 231, and 272.

Purpose of this chapter

The purpose of this chapter is to describe the potential highway impacts that would result if the contents of the 10,700 annual carloads handled on the PCC system were moved in trucks to river ports or an inland shuttle-train facility. This chapter describes:

- The commodities and types of trucks used in short-haul movements to river ports or inland grain subterminals;
- The tare and gross axle weights of these trucks;
- The pavement impact and cost models used in the study; and
- The estimated pavement costs and truck user fees generated from the incremental truck traffic.

Commodities and truck types

The types of trucks used and the axle weight distributions are important parameters in pavement cost analysis. Tractor and trailer configurations and truck weights are largely a function of the loading characteristics and densities of the commodities.

Grain is the primary commodity transported on the PCC, comprising 83 percent of the loaded cars originated or terminated in 2000. Food products (mostly canned and frozen vegetables) accounted for another 8 percent of the PCC's carloads. The remaining 980 carloads consisted of chemicals, coal, petroleum products, and farm equipment or machinery.

Rocky Mountain Double trucks

If the PCC rail lines are abandoned, more grain will be trucked to Tri-Cities, Windust, Central Ferry, or Ritzville in Rocky Mountain Doubles. A Rocky Mountain Double (RMD) consists of a tractor pulling a semitrailer, followed by a smaller "pup" trailer. Overall, this truck has seven axles:

- A single steering axle on the tractor;
- Two sets of tandem axles: a tractor driving axle and a tandem axle underneath the semitrailer; and
- Two single axles underneath the pup trailer.

The RMD is assumed to have 26 wheels. Except for the steering axle, each axle on the truck is assumed to have four tires. The use of super-single tires on the semitrailer or pup trailer would violate this assumption and could result in biased equivalent single-axle load (ESAL) estimates. These potential effects are considered through sensitivity analysis.

When fully loaded, the RMD weighs 105,500 pounds. However, the tare weight of the truck varies with the trailers' dimensions and materials. Both the semitrailer and pup trailer are "hopper" trailers, constructed with one or more hopper bins. However, there are many variations in length, width, and number of bins. Semitrailers may range from 40 to 45 feet in length, with one or two hopper bins. A pup trailer may range from 18 to 24 feet in length. Some trailers of the same dimensions are heavier than others due to differences in materials.

Variations in truck weights between private and commercial haulers may be the result of equipment differences. Several of the elevator and grower associations own Rocky Mountain Doubles and provide their own trucking services. On average, these associations report tare weights ranging from 32,000 to 35,500 pounds. U.S. Department of Transportation studies provide some information about the tare weights of commercial trucks. A 1995 working paper prepared for the *Comprehensive Truck Size and Weight Study* lists a tare weight of 31,700 pounds for a tractor, a 42-foot semitrailer, and a 21-foot pup trailer.[3] This overall truck weight closely reflects the individual component weights shown in Table 2.[4]

Table 2. Typical Tractor and Hopper Trailer Weights Used in USDOT Truck Size and Weight Study

Equipment Description	Empty Weight
Long Wheel-Base Tractor	14,900
42-Foot Hopper Semitrailer	9,500
21-Foot Full Hopper Trailer	7,150
Total Equipment Weight	31,550

Because of variations in equipment weights, a midpoint tare weight of 33,500 pounds is used in this study. The weight of the Rocky Mountain Double is distributed among the five axle groups as shown in Table 3. These tare weight distributions reflect the relative weights of the components shown in Table 2.

[3] The RMD tare weight is shown in Table 1.10 of: Comprehensive Truck Size and Weight (TS&W) Study Phase 1-Synthesis, Truck Costs and Truck Size and Weight Regulations− Working Paper 7, February 1995. Prepared for the U.S. Department of Transportation by the Battelle Team.

[4] Ibid. − Table 1.5.

Table 3. Axle Weight Distributions for Rocky Mountain Double		
Axle Group	**Tare Weight**	**Gross Weight**
Tractor Steering Axle	6,500	9,500
Tractor Tandem Axle	10,500	32,000
Semitrailer Tandem Axle	9,000	31,500
Pup Trailer: Axle 1	4,000	16,500
Pup Trailer: Axle 2	3,500	16,000
Total: All Axles	**33,500**	**105,500**

The distributed gross weight of the truck (Column 3 of Table 3) is based on data from Transportation Research Board (TRB) Special Report 225: *Truck Weight Limits*.[5] All of the distributed weights conform to legal axle weight limits and to the federal bridge formula.

The net weight or payload is the difference between the gross and tare weights. The payload of a grain-hauling Rocky Mountain Double is 72,000 pounds or 36 tons, based on a midpoint tare weight of 33,500 pounds. However, the payload may vary from 35 to 37 tons depending on the tare weights of the trailers.[6]

The Rocky Mountain Double with hopper trailers is a specialized truck. Hopper trailers are very efficient, allowing for rapid bottom discharge of grain. However, it is difficult for truckers to obtain a backhaul for these trailers. Certain dry fertilizers and other finely-divisible commodities can be hauled in them. However, a backhaul usually requires that the trailers be cleaned thoroughly before they are re-loaded with grain.

On very short trips, because of the specialized nature of the equipment and risks of contamination, the RMD runs empty for half of the round-trip miles.[7] The truck unloads the grain and returns home empty. This empty-mile factor is slightly higher than the 40 percent factor used for hopper trailers in the *USDOT Comprehensive Truck Size and Weight Study*.[8] However, the majority of trucks used to haul grain to Snake or Columbia

[5] The axle weight distributions for a 7-axle Rocky Mountain Double are shown in frame (f) of Figure 4.3 in: *Truck Weight Limits: Special Report 225*. Transportation Research Board, 1990. The same percentage distributions are used in this study with a slightly higher total truck weight.

[6] A 263,000-pound covered hopper car is typically loaded with 100 net tons. Thus, a 263,000-pound rail car is equivalent to 2.8 Rocky Mountain Doubles. A 286,000-pound covered hopper car with a net load of 111 tons is typically equal to 3.1 Rocky Mountain Doubles.

[7] Source: telephone interviews with grain shippers in eastern Washington.

[8] The empty-mile ratio is derived from Appendix A of a report by Jack Faucett Associates: *The Effects of Truck Size and Weight Limits on Truck Costs*. A Working Paper prepared for the U.S. Department of Transportation, October, 1991.

River ports are owned or leased by shipper associations. Very few backhaul opportunities exist for these trucks.

Conceivably, bulk commodities such as coal and petroleum products could be transported in Rocky Mountain Doubles. However, most of these shipments occur in commercial vehicles rather than in shipper-owned trucks. For infrequent short-haul movements, commercial truckers are more likely to use a single semitrailer than a specialized RMD.

Combination 5-axle trucks

For the most part, manufactured and processed goods move in 5-axle tractor-semitrailer combinations, commonly referred to as "semis." Because of the tandem-axle exception to Bridge Formula B, most of these trucks are loaded to 80,000 pounds.[9]

Refrigerated van trailers

A significant quantity of canned and frozen vegetables is shipped on the PCC in refrigerated boxcars. If these perishable products are shifted to trucks, they will be shipped in refrigerated van trailers (reefers). The typical tare weight of a combination 5-axle truck with a refrigerated van trailer is 28,700 pounds. This tare weight includes the weight of a conventional tractor (13,900 pounds) and a tandem-axle semitrailer weighing 13,300 pounds.[10] If this truck operates at 80,000 pounds, it can accommodate 51,300 pounds of payload. Typical weight distributions for this truck are shown in Table 4.

Refrigerated van trailers are more flexible than hopper trailers and can be used to backhaul similar commodities in canned, packaged, or boxed form. According to Faucett (1991), refrigerated van trailers incur 15 percent empty miles per year.[11]

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[9] Bridge Formula B allows 68,000 pounds on any consecutive set of tandem axles when the distance from the center of the first axle to the center of the fourth axle is at least 36 feet. This exception allows some shorter wheel-base vehicles such as 40-foot hopper trailers to operate at 80,000 pounds with a sufficient tractor wheel base so that the "tractor bridge" is not in violation of the bridge formula.

[10] The refrigerated van tare weight is computed from equipment weights shown in Table 1.5 of *Comprehensive Truck Size and Weight (TS&W) Study Phase 1-Synthesis, Truck Costs and Truck Size and Weight Regulations: Working Paper 7*, February 1995. Prepared for the U.S. Department of Transportation by the Battelle Team.

[11] The empty-mile ratio for refrigerated vans is derived from Appendix A of a report by Jack Faucett Associates: *The Effects of Truck Size and Weight Limits on Truck Costs*. A Working Paper prepared for the U.S. Department of Transportation, October, 1991.

Table 4. Axle Weight Distributions for 5-Axle Truck with Refrigerated Van Semitrailer		
Axle Group	**Tare Weight**	**Gross Weight**
Tractor Steering Axle	6,000	12,000
Tractor Tandem Axle	10,400	34,000
Semitrailer Tandem Axle	12,300	34,000
Total: All Axles	**28,700**	**80,000**

Tanker trailers

Chemical and petroleum products move in specialized tanker trailers that are similar in weight and length to hopper trailers. The tare weight of a tanker truck is typically 24,800 pounds (Table 5)[12]. If this truck operates at 80,000 pounds, it can accommodate 55,200 pounds of payload. According to Faucett (1991), tanker trailers incur 45 percent empty miles per year.[13]

Table 5. Axle Weight Distributions for 5-Axle Truck with Tanker Semitrailer		
Axle Group	**Tare Weight**	**Gross Weight**
Tractor Steering Axle	6,000	12,000
Tractor Tandem Axle	9,800	34,000
Semitrailer Tandem Axle	9,000	34,000
Total: All Axles	**24,800**	**80,000**

Flatbed trailers

A small amount of farm equipment or machinery moves via the PCC. Heavy machinery and equipment typically move on flatcars. If shipped by truck, these products would move on flatbed trailers. The typical tare weight of a 48-foot flatbed semitrailer and tractor is 26,400 pounds (Table 6). This includes the weight of a conventional tractor and a tandem-axle semitrailer weighing 12,500 pounds.[14] Farm tractors and machinery are non-divisible loads. Thus, the average truck payload is assumed to be the same as the average flatcar load—21 tons or

[12] The tanker truck tare weight is computed from equipment weights shown in Table 1.5 of *Comprehensive Truck Size and Weight (TS&W) Study Phase 1-Synthesis, Truck Costs and Truck Size and Weight Regulations: Working Paper 7*, February 1995. Prepared for the U.S. Department of Transportation by the Battelle Team.
[13] Ibid.
[14] The flatbed truck tare weight is computed from equipment weights shown in Table 1.5 of *Comprehensive Truck Size and Weight (TS&W) Study Phase 1-Synthesis, Truck Costs and Truck Size and Weight Regulations: Working Paper 7*, February 1995. Prepared for the U.S. Department of Transportation by the Battelle Team.

36,000 pounds.[15] According to Faucett (1991), flatbed semitrailers incur 25 percent empty miles per year.[16]

Table 6. Axle Weight Distributions for 5-Axle Truck with Flatbed Semitrailer		
Axle Group	**Tare Weight**	**Gross Weight**
Tractor Steering Axle	6,000	10,000
Tractor Tandem Axle	9,800	30,000
Semitrailer Tandem Axle	10,600	28,400
Total: All Axles	**26,400**	**68,400**

The tare and gross axle weights shown in Tables 3 through 6 are used to compute gross and tare ESAL factors for each type of truck.

Pavement cost factors

Three of the most important concepts in pavement cost analysis are:
1. The type and structural capacity of the pavement;
2. The service life of the pavement; and
3. The 18-kip ESALs generated per truck trip.

The structural capacity of a pavement is "the maximum load and number of repetitions it can carry."[17] The maximum number of load repetitions that a pavement can carry is its *structural life*. Structural life may be different from pavement service life, which is measured in years. Pavement service life may be affected by environmental deterioration as well as by structural capacity.

Types of pavements

The structural capacities of pavements are affected by the type, quality, and placement of materials and the quality of the underlying soil. Hard-surfaced pavements consist of two general types: flexible and rigid. Flexible pavements are composed of multiple layers of materials resting upon a prepared subgrade. The surface layer is usually an asphalt-concrete layer or a bituminous surface treatment. A bituminous surface treatment (BST) is used on roads with lower traffic volumes—e.g., less than 2,000 vehicles per day. Asphalt-concrete (AC) surfaces are used for roads with higher traffic levels, especially where higher percentages of truck traffic are present. Rigid pavement surfaces are composed of

[15] This value is computed from 1998-2000 sample waybill data.
[16] This empty-mile ratio is derived from Appendix A of a report by Jack Faucett Associates: *The Effects of Truck Size and Weight Limits on Truck Costs*. A Working Paper prepared for the U.S. Department of Transportation, October, 1991.
[17] American Association of State Highway and Transportation Officials. *Pavement Management Guide*, 2001.

Portland Cement Concrete. Because of their higher initial costs, concrete pavements are used primarily for high-volume roads.

Pavement structural number

The structural capacity of a flexible pavement is a function of the individual layers. The *structural number* is a composite value that reflects the material composition, thickness, and location of each layer. A heavy pavement is one with a structural number of 4.6 or greater.[18] A medium pavement has a structural number of 3.1 to 4.5. A light pavement is one with a structural number of less than 3.0.

The structural capacity of a rigid pavement is a function of its slab thickness. A Portland Cement Concrete pavement is classified as:[19]

- Heavy − if the slab is thicker than 9.0 inches (or 8 inches if continuously reinforced)
- Medium − if the slab is 7.1 to 9.0 inches thick (or at least 6 inches if continuously reinforced)
- Light − if the slab is 7 inches thick or less and is not continuously reinforced

Equivalent single-axle loads

With the exception of studded-tire wear, automobile traffic has little effect on pavements. According to the United States Department of Transportation:

> *Except for roads with relatively light traffic volumes, the rate of pavement deterioration is dependent primarily on the number of 18,000 pound (18 kip) equivalent single-axle loads (ESALs).*[20]

As noted earlier, several types of trucks are used to haul the commodities currently moving over the PCC rail network, including: Rocky Mountain Doubles, refrigerated van trailers, tanker trailers, and flatbed trailers. The impacts of a truck upon a pavement depend primarily on the structural capacity of the pavement and the truck's axle configuration and weights. In pavement impact analysis, the effects of different axle types are accounted for by converting the axle weights to ESALs. An ESAL represents the impact of a certain axle type and load in comparison to the impact of an 18,000-pound single axle. For example, an axle with an ESAL factor of 1.2 has 1.2 times the impact of a single 18,000-pound

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[18] These definitions are derived from: Federal Highway Administration, *HPMS Field Manual*, Washington, D.C., 2000.
[19] Ibid.
[20] United States Department of Transportation. *Highway Economic Requirements System, Technical Report*, Page 6-11, June, 2000.

axle.[21] In general, tandem and triple axles cause less damage per ton than single axles. For example, a 34,000-pound tandem axle generates only 1.1 times the impact of an 18,000-pound single axle on a flexible pavement.

Primary data sources

Pavement rehabilitation costs

The WSDOT P1 Pavement Preservation Model is the primary source of pavement resurfacing and rehabilitation costs for this study. Paving costs for several types of highways have been provided by the WSDOT Eastern Region office. These unit costs have been derived from the P1 Model. They reflect data from 170 paving contracts during the 1997-99 biennium. These paving costs are specific to eastern Washington and applicable to the potentially-impacted highways.

In addition, average resurfacing costs have been estimated for highway functional classes. These unit costs were developed by FHWA for use in the Highway Economic Requirements System (HERS). They have been indexed to 2000 levels and adjusted for construction prices in Washington State. These costs have been reviewed by the WSDOT Eastern Region office. Their applicability to eastern Washington is illustrated later through comparisons with the P1 paving costs.

Highway structural and baseline traffic data

The two primary sources of highway structural and traffic data for this study are:

1. The 2000 Highway Performance Monitoring System (HPMS) database
2. The 2001 Washington State Pavement Management System (WSPMS) database

The pavement cost estimates presented in this report are based on structural data for 947 segments from the 2001 WSPMS. These segments comprise 645 centerline miles and 1,293 lane miles. Where possible, key inputs derived from the WSPMS (such as structural numbers and current truck traffic levels) have been compared to HPMS sample segments. In most cases, structural and traffic data derived from the two sources are in close agreement for overlapping segments. However, in some cases,

[21] The ESAL factors used in this illustration are computed from equations developed by the American Association of State Highway and Transportation Officials (AASHTO). In this study, an ESAL factor for each type of truck and commodity is computed for each individual WSPMS segment over which the truck travels using the AASHTO axle-load equivalency formulas for single and tandem axles. Separate formulas are used for flexible and rigid pavements.

HPMS data for longer highway segments have been substituted for multiple short WSPMS segments.[22]

Baseline equivalent single-axle loads have been computed for each WSPMS segment using ESAL factors for single-unit trucks, double-unit trucks, and longer-configuration vehicles (i.e., *trains*).[23] Design-lane (right-lane) ESALs have been derived from typical lane distribution factors.[24]

This report describes potential changes in truck traffic that could affect WSDOT's normal pavement preservation program. Before describing the models and analytical methods used in this study, the essential features of WSDOT's pavement preservation program are highlighted.

Pavement preservation strategies and paving costs

Asphalt-concrete pavements

In most cases, asphalt-concrete pavements are preserved through resurfacing improvements. Generally, AC pavements require resurfacing every 10 to 15 years. The average life expectancy of asphalt-concrete pavements is 11 years in eastern Washington. However, actual resurfacing cycles may be longer for low-traffic roads and shorter for high-traffic roadways.

WSDOT's strategy is to resurface pavements at the most cost-effective Pavement Structural Condition (PSC) value in order to achieve the lowest life-cycle cost (RCW 47.05). The Washington State Pavement Management System uses a PSC rating of 50 as a "due indicator" of the need for pavement rehabilitation. The due indicator reflects a philosophy of minimizing pavement overlay thickness. The minimum overlay thickness is attained by rehabilitating pavements when less than 10 percent of the segment exhibits medium-to-high severity fatigue (alligator) cracking.

Table 7 shows average preservation costs for all classes of "due" AC pavements in eastern Washington. These unit costs were derived from the P1 model.[25] The generic lane-mile estimates for urban and rural highways

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[22] Presumably, the structural numbers for the HPMS segments reflect detailed data about conditions and accumulated distresses of old AC surface layers. Moreover, the longer segments provide greater continuity for the impact analysis.
[23] These factors are specified on page 45 of the WSPMS Pavement Management Software Guide.
[24] These factors are shown on page 64 of the WSPMS Pavement Management Software Guide.
[25] The P1 Model has been developed, maintained, and applied now for 10 years. The most recent cost update of the model used unit costs from one-hundred-seventy (170) P1 Preservation paving contracts completed from 1997-1999.

are based on a prescribed roadway width for each category that includes shoulder widths. The costs shown in Column 2 of Table 7 include paving, safety, and drainage costs. The paving costs per lane mile (exclusive of safety and drainage restoration) are shown in Column 3. These costs reflect a typical paving depth of .15 feet or 1.8 inches.[26]

It is important to note that the P1 Preservation Program is not intended to build additional structural capacity into a pavement. The preservation program maintains the existing pavement in serviceable condition and protects the underlying pavement materials.[27]

Table 7. 2001 Pavement Preservation Costs for Due Asphalt-Concrete Pavements in Eastern Washington

	Thousands of Dollars per Lane Mile	
Highway Type	**Total Cost**	**Paving Cost**
Rural Two-Lane	$104	$97
Rural Multi-Lane	$102	$94
Urban Two-Lane	$151	$140
Urban Multi-Lane	$128	$119

Source: *WSDOT, 2001 P1 Model Update. Total Cost includes mobilization, construction engineering, contingencies, preliminary engineering, and basic safety/spot preservation.*

Past-due AC pavement costs

The costs shown in Table 7 are based on optimal resurfacing—i.e., the resurfacing of pavements when the PSC reaches 50. If pavements are rehabilitated at lower PSC values, the costs will be much greater than if they are resurfaced at the optimal time. This general relationship is illustrated in Table 8. For example, the paving cost of a segment that is more than six years past due will be 100 percent greater than the optimal paving cost.

Table 8. Increase in Pavement Preservation Costs for Past-Due Projects

Years Past Due	Increase in Cost
Less than 3	25%
3-to-6	50%
Greater than 6	100%

Source: *Washington State Highway Pavements: Trends, Conditions, and Strategic Plan, May 1999, Annex B.*

[26] Source: WSDOT, Eastern Region Office.
[27] However, structural enhancement may occur over time for existing pavement cross sections at marginal structural sufficiency levels.

Currently, 23 percent of state highway miles are past due for resurfacing.[28] Instead of spending $102,000 to $104,000 per lane-mile to resurface rural highways in eastern Washington, WSDOT must spend $138,000 to $140,000 per lane-mile for past due pavements. At a past due rate of 23 percent, actual pavement rehabilitation costs range from $110,000 to $112,000 per lane-mile.[29]

Bituminous surface treatments

Bituminous surface treatments (BST) highway segments are preserved through frequent surfacing treatments. The average BST segment is surfaced every six years at a cost of $12,100 per lane-mile. This cost provides for the application of a **non-structural** friction course only.

WSDOT's BST pavement preservation strategy is based on the assumption that these routes will be maintained as low-volume, low-ESAL highways. If the annual ESALs increase significantly on BST highways, it may be necessary to convert them to AC pavements to provide a structurally-sufficient roadway.

Portland cement concrete pavement preservation costs

Currently, WSDOT is rehabilitating 30-year-old concrete pavements by increasing the strength of the joints. This is accomplished by retrofitting the joints with steel dowel bars, which provide enhanced load transfer capabilities. The average cost of a dowel bar retrofit is $330,000 per lane mile.[30] The full replacement cost of a Portland cement concrete pavement is $900,000 per lane mile in eastern Washington.

Effects of budgetary constraints

Because of overall budgetary constraints, the Washington Legislature has not provided WSDOT with sufficient funding in the P1 Program to address long-term pavement rehabilitation needs. Portland cement concrete pavement rehabilitation is not fully funded.[31] Asphalt-concrete pavement (ACP) and BST routes were funded at 60 percent of the allocation need to meet lowest life cycle cost for the 2003-05 biennium.[32] As illustrated later, these budgetary constraints will result in higher pavement rehabilitation costs for highways affected by increased truck traffic.

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[28] Source: WSDOT Eastern Region office.
[29] This weighted-average assumes that 23 percent of highway miles in eastern Washington are past due, including 23 percent of rural two-lane highways and 23 percent of rural multi-lane highways.
[30] This estimate is based on available contract costs and due lane miles.
[31] Source: WSDOT, Eastern Region Office.
[32] Ibid.

As noted earlier, the intent of the pavement preservation program is to maintain pavements in serviceable condition at roughly the same structural number through the timely application of overlays. The pavement preservation plan considers normalized or long-term traffic growth. However, the plan does **not** consider the potentially-significant increase in heavy truck traffic that may result from rail-line abandonment. The purpose of this chapter is to estimate the additional pavement costs associated with this unforeseen traffic. The projected costs shown in this chapter are **in addition to** the normal preservation costs that will be incurred as a result of existing truck traffic.

Analytical approaches to pavement cost analysis

The additional pavement cost resulting from potential rail-line abandonment cannot be known with certainty until future actions are taken by WSDOT. The objective of this chapter is to provide reasonable estimates of these future costs using methods and assumptions that are consistent with WSDOT design and maintenance practices.

Two methods of estimating truck-related pavement costs have been used in previous studies: (1) an average cost approach and (2) an incremental thickness approach. Both methods are used in this chapter. As shown later, they produce similar but not identical results.

Average cost method

This approach was developed originally by Federal Highway Administration in the *1982 Highway Cost Allocation Study* for allocating pavement preservation costs among vehicle classes.[33] FHWA referred to this method as a "marginal cost" approach. Technically, this is true only if certain assumptions are met.

In this method, marginal pavement cost is defined as the change in cost resulting from an additional ESAL. A key feature of this approach is that the effects of trucks are analyzed independently of the order in which they are added to or subtracted from the traffic stream. Federal Highway Administration adopted the ESAL approach because the previously-used "incremental method" allocated most of the economies of thicker pavements to the heaviest vehicle classes.[34]

[33] The logic of the preservation cost approach is described in Appendix E of the *1982 Highway Cost Allocation Study*.
[34] In the older incremental approach, the change in pavement cost was defined as the cost of a vehicle weight class (e.g., trucks weighing more than 80,000 pounds) when the entire class is added to or removed from the traffic stream. However, the incremental highway cost attributable to a vehicle class is dependent upon the order or sequence in which it is hypothetically added to or removed from the traffic stream. If the heaviest class of

Key assumptions

The average/marginal cost approach is premised upon several key assumptions:

1. Structural capacity is defined as the maximum number of axle loads that a pavement can accommodate before it is rehabilitated. Structurally, the life of a pavement can be measured in equivalent single axle loads or ESALs.
2. When a pavement reaches its terminal serviceability level, it is restored or rehabilitated through resurfacing.
3. Resurfacing restores the structural capacity of the pavement but usually leaves it no better-off (or worse-off) than at the beginning of the deterioration period.
4. For a given functional class of highway, marginal pavement cost is the same as average pavement cost. However, marginal pavement costs may vary greatly among functional classes.

Key calculations

The marginal pavement cost of a truck trip within a given functional class is estimated through a multi-step process:

1. The ESAL life is computed from AASHTO equations using a typical structural number for the functional class.
2. An average rehabilitation cost per mile is estimated for the functional class.
3. An average (marginal) cost per ESAL is computed by dividing the rehabilitation cost per lane-mile by the ESAL life.
4. The axle loads of a truck or a particular class of trucks are converted into ESALs.
5. The ESAL factor per truck is multiplied by the cost per ESAL to yield a cost per vehicle-mile of travel (VMT).

Key refinements

The specificity of this approach can be greatly improved through two refinements:

1. Instead of using a typical structural number for the functional class, the ESAL life of each impacted segment can be computed.
2. The portion of resurfacing cost that is unaffected by truck traffic can be excluded from the marginal cost calculation.[35]

The first refinement is accomplished by reading structural data for each impacted segment from the WSPMS database. The same equations are

vehicles is the last one to be added or removed, then its cost responsibility will be much lower than if it is added or removed earlier in the sequence.

[35] By definition, the proportion of pavement rehabilitation cost attributable to environmental decay or deterioration is not included in the marginal pavement cost of truck travel.

used in the ESAL life calculations. However, the results are much more precise. The second refinement is more difficult to implement. Several approaches are possible, two of which are discussed next.

Maximum pavement life approach
A simplified way of analyzing environmental deterioration was developed by FHWA for use in the Highway Economic Requirements System (HERS). This approach—called the maximum life approach—is fairly theoretical in nature. Each type of pavement is assigned a maximum feasible life. The maximum life is the number of years that the pavement will last if it is subjected to little or no heavy truck traffic. In HERS, the maximum life is used to enforce a minimum annual rate of environmental-related deterioration.[36]

The maximum life approach works best for concrete pavements. Several Portland cement concrete sections with only light truck traffic are still in service after 75 years. These cases provide clear empirical evidence of the maximum life of a concrete pavement without significant heavy truck traffic. However, it is much more difficult to observe maximum feasible lives for asphalt-concrete pavements. There are many variations in layer thicknesses and materials. The flexible pavements that are subjected to very light traffic loads are usually low-type pavements with thin ACP or bituminous surfaces.[37] Generally, the observed decay lives of low-type pavements are not transferable to intermediate and high-type pavements. Because of the absence of empirical evidence, estimates of the maximum potential lives of flexible pavements must be derived from engineering judgment or rules-of-thumb.

Causal rehabilitation models
The capability to isolate traffic-related and environmental-related pavement deterioration has improved with time. The Federal Highway Administration initially developed a set of pavement distress and load-share models for the *1982 Highway Cost Allocation Study*. These models describe the relative shares of pavement rehabilitation costs attributable to environmental (non-load) and traffic (load-related) factors. The models—collectively referred to as National Pavement Cost Model (NAPCOM)—were revised and improved for the *1997 Federal Highway Cost Allocation Study*.

NAPCOM uses highway information supplied by states for the Highway Performance Monitoring System. However, the HPMS data have been

[36] If a functional form is assumed for the deterioration curve (e.g., negative exponential), it is possible to estimate the percentage loss in pavement serviceability from environmental forces during a typical design period.
[37] Many such pavements don't have treated bases or subbases. Moreover, the base layers may not be sufficiently deep to control frost action. Thus, the pavements may be affected by frost heave, soil swelling, or variable subgrade support.

supplemented with additional state or climatic zone data needed for the NAPCOM models, including: freeze-thaw cycles, freezing index, Thornthwaite moisture index, modulus of subgrade reaction, average annual rainfall, average maximum temperature, and concentration of summer thermal efficiency.[38]

For flexible pavements, NAPCOM analyzes the following distresses:

- Traffic-related present serviceability rating (PSR) loss (roughness)
- Fatigue cracking
- Rutting
- Loss of skid resistance
- Expansive clay-related PSR loss
- Thermal-related cracking

The first four distresses are loaded-related. However, the last two distresses—expansive clay-related PSR loss and thermal-related cracking—are non-load or environmental distresses.[39]

Non-load shares of pavement rehabilitation costs

In 2001 FHWA released a State Highway Cost Allocation spreadsheet program, which uses the most recent NAPCOM models and procedures. Table 9 shows the estimated percentages of non-load flexible pavement rehabilitation costs in Washington State derived from the cost allocation spreadsheet.[40] As Table 9 shows, the estimated contribution of non-load factors to pavement preservation cost is less than four percent for Rural Interstate highways in Washington State. However, the non-load contribution increases to 12.5 percent for Rural Other Principal Arterial highways and 16.7 percent for Rural Minor Arterial highways. The highest non-load cost responsibility is nearly 30 percent for Rural Major Collector highways. The increasing non-load cost responsibility for lower highway classes is primarily the result of PSR loss due to expansive clay soils.[41]

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[38] United States Department of Transportation. 1997 Federal Highway Cost Allocation Study, Appendix F. Allocation of Pavement Rehabilitation Costs Using NAPCOM.
[39] Rigid pavement distresses consist of: (1) traffic-related PSR loss, (2) faulting, (3) loss of skid resistance, (4) fatigue cracking, (5) spalling, and (6) soil-induced swelling and depression.
[40] These estimates are based on the default data elements included in the spreadsheet for functional highway classes in Washington State.
[41] NAPCOM's expansive-clay PSR loss model includes the following parameters: (1) exchange sodium capacity, (2) percent clay of subgrade soil (grain size less than 0.002 mm), (3) the effective depth of asphalt layer (equivalent to 2.3 times its thickness), (4) the cation exchange capacity of the subgrade soil, (5) activity index (which is the plasticity index divided by the percent clay of the soil), (6) the range in values of the Thornthwaite moisture index for a 20-year period, and (7) the number of years since pavement construction or reconstruction.

Table 9. Percent of Flexible Pavement Rehabilitation Costs in Washington State Due to Non-Load (Environmental) Factors			
Functional Class	**Expansive Soil**	**Thermal Cracking**	**Total Non-Load**
Rural Interstate	0.2%	3.5%	3.7%
Rural Other Principal Arterial	5.3%	7.2%	12.5%
Rural Minor Arterial	10.2%	6.4%	16.6%
Rural Major Collector	22.4%	7.2%	29.6%
Urban Interstate	0.6%	3.1%	3.7%
Urban Principal Arterial	0.9%	6.9%	7.8%

After the contribution of environment to pavement rehabilitation cost has been isolated, the residual cost is traffic-related. Theoretically, each ESAL has an effect on overlay thickness and hastens the rehabilitation of a pavement. Admittedly, the effect of a single ESAL is microscopic and cannot be observed at the time it occurs. Nevertheless, each ESAL consumes a portion of the structural life of a pavement (i.e., its ESAL life). In the marginal cost approach, the consumption of pavement life is recognized at the time the load is applied even though the related expenditure doesn't occur until later.

Resurfacing unit costs

The average/marginal cost method requires resurfacing costs for individual functional classes. Table 10 shows resurfacing costs per lane-mile for rural highway classes. These costs were developed by FHWA for the Highway Economic Requirements System.[42] However, they have been adjusted for construction costs in Washington State.[43] They include the cost of overlaying existing pavements, bringing shoulders up to grade, and minor drainage restoration work.

[42] The resurfacing costs were originally developed by FHWA using 1997 prices. However, they have been updated to 2000 levels using FHWA price indices for pavement resurfacing in rural areas.
[43] The costs shown in Table 10 have been adjusted for construction prices in Washington State through means of a "state cost factor." The state cost factor is the ratio of the Washington State composite price index to the United States composite price index. Because construction prices may fluctuate from year to year, a multi-year average is used for the 1997-2000 period. This approach is adapted from HERS, in which the state cost factor represents a three-year moving average. The Washington State composite index was missing for 1998. Therefore, the multi-year average is based on data for 1997, 1999, and 2000. The computed multi-year state cost factor is 1.21.

Table 10. 2000 Resurfacing Costs per Lane Mile Adjusted for Washington State Construction Costs			
	Thousands of Dollars per Lane Mile		
	Terrain		
Functional Class	**Flat**	**Rolling**	**Mountainous**
Rural Interstate	$165	$165	$204
Rural Other Principal Arterial	$103	$103	$151
Rural Minor Arterial	$86	$92	$145
Rural Major Collector	$49	$57	$72

***Source**: 1997 FHWA costs indexed to 2000 levels using FHWA Construction Price Indexes for pavement surfacing in rural and urban areas and then adjusted by the Washington State cost factor.*

The unit costs shown in Table 10 represent the average costs of preserving/restoring the structural capacity of different classes of highways. The higher costs for higher functional classes reflect the thicker overlays needed for heavier traffic levels.[44] When these functional-class costs are weighted by lane-miles in eastern Washington, the resulting average resurfacing cost is $110,000 per lane-mile. This estimate is very close to the WSDOT rural paving cost of $110,000 to $112,000 per lane-mile discussed earlier.

Unit costs per ESAL and truck-mile

Average pavement costs per ESAL and vehicle-mile are shown in Table 11 for an 80,000-pound 5-axle truck traveling over rural highways in eastern Washington. Several assumptions and intermediate calculations are reflected in this example.

- Rural Interstate highways are assumed to be four-lane divided highways. All other highways are assumed to be simple two-lane roads. To maintain consistent highway geometry, both lanes of a simple two-way road are resurfaced at the same time and paved to the same depth. However, the decision to resurface a divided highway in one direction is independent of resurfacing decisions in the opposite direction. Thus, the resurfacing costs per mile for both types of highway are computed by multiplying the lane-mile cost times two.
- The ESAL life of each highway is computed at the mean structural number of the class. The mean structural numbers are weighted averages for asphalt-concrete pavements in eastern Washington.[45]

[44] In addition, the cost shown in Table 10 reflects the additional costs of resurfacing wider shoulders and variations in resurfacing cost due to terrain.
[45] The mean structural numbers were computed from the 2000 HPMS database. The weight variable is roadway miles (section length).

ESAL lives are estimated for these structural numbers using pavement life equations from HERS (appendix).[46]

- The ESALs per mile generated by an 80,000-pound truck are computed from AASHTO axle-load equivalency formulas. For divided highways, the ESALs are converted to design-lane ESALs using a lane distribution factor of .90.
- The non-load shares of rehabilitation cost shown in Table 9 are not reflected in the unit costs.

Table 11. Average Costs per ESAL and VMT for 5-Axle Truck Travel on Rural Highways in Eastern Washington

Functional Class	SN	ESAL Life	Cost per ESAL	Cost per VMT
Interstate	5.3	5,167,630	$0.06	$0.13
Other Principal Arterial	4.2	1,406,861	$0.13	$0.30
Minor Arterial	3.0	325,217	$0.47	$1.16
Major Collector	2.5	173,078	$0.46	$1.14

In the *1997 Highway Cost Allocation Study*, FHWA estimated a marginal pavement cost of 12.7 cents per truck-mile for an 80,000-pound 5-axle truck traveling over a Rural Interstate highway. The Rural Interstate cost per VMT shown in Table 11 is very close to the FHWA marginal cost. Although there are no benchmarks for the other unit costs, their relationships to the Rural Interstate cost seem reasonable given the resurfacing costs shown in Table 10 and the ESAL lives shown in Table 11.

Although the estimates shown in Table 11 are insightful, they are not used in this chapter. A cost per ESAL is computed for each WSPMS segment based on its structural number and ESAL life.[47] Moreover, the cost per VMT is unique to each WSPMS segment, reflecting the lane distribution of truck traffic.

[46] The HERS pavement life equations are derived from the AASHTO pavement design equations. They reflect slight modifications based on FHWA field data. The HERS equations predict the same ESAL lives as the AASHTO equations for much of the range of structural numbers. However, the HERS equations predict slightly higher ESAL lives at the low end of the structural number (SN) range and slightly lower ESAL lives at the high end. The HERS ESAL life curves appear to closely match field data. In HERS, the deterioration curves can be empirically adjusted to match deterioration curves from a state's pavement management system. In this example, the allowable decline in PSR is 1.5.

[47] The process used in computing structural numbers and the layer coefficients are described in the Appendix A.

Relevance to marginal cost

Costs computed in this manner have been described by FHWA as marginal costs. Technically, this definition holds true only in restricted circumstances. Specifically, two key assumptions must be met:

1. *The existing structural capacity of the highway must be matched closely to the structural demands of the truck traffic*. This is a reasonable assumption since WSDOT designs all highways for a consistent performance period using AASHTO design procedures.
2. *The marginal cost per ESAL is the same as the average cost per ESAL*. This is a reasonable assumption for relatively small changes in traffic. However, its relevance may decrease with the percentage increase (or decrease) in truck traffic. Because of economies of scale in pavement thickness, the incremental overlay cost attributable to a new increment of truck traffic may be less per ESAL than the historic average. However, after a significant increment of new traffic, the roadway may be reclassified and redesigned. At some point a thick structural overlay may be added or the pavement may be reconstructed. In these cases, average functional-class costs may understate the change in pavement cost.

Incremental thickness approach

The incremental thickness method is an abstract representation of the pavement rehabilitation process using overlays. It is based on the AASHTO rehabilitation/overlay method and uses AASHTO pavement design equations. The objective of the method is to determine the additional overlay thickness needed to provide the enhanced structural capacity necessary to accommodate the new truck traffic.

The incremental method is sensitive to the accuracy of baseline data and forecasts of additional truck traffic. It is premised upon several key assumptions regarding pavement maintenance practices and historic rehabilitation procedures:

1. The impacted highway segments have been designed using AASHTO pavement design guidelines.
2. The structural numbers of the pavements are closely matched to the projected baseline truck traffic for the current design period.
3. Asphalt pavements are being preserved or rehabilitated through pavement overlays.

These assumptions are clearly satisfied in this study. WSDOT has used AASHTO design procedures for several decades. Pavement thicknesses and structural numbers are closely matched to historic truck traffic levels. Moreover, as part of its long-term pavement preservation program, WSDOT strives to resurface pavements in a timely manner to protect the underlying materials and provide a consistent 10- to 15-year performance period.

The overlay method of restoring and adding structural capacity

Overlays are the most common cost-effective method of restoring and increasing the structural capacity of pavements. "Overlays are generally used either to improve pavement surface irregularities (such as roughness, studded tire wear, etc.) or increase the pavement structural capacity or both."[48]

Pavement structural deficiencies may arise from "conditions that adversely affect the load carrying capability of the pavement structure."[49] At the time of an overlay, the existing surface layer may exhibit fatigue (or alligator) cracking in the wheel paths, rutting in the wheel paths, transverse (longitudinal) cracking, and localized areas of collapse or disintegration—which are indications of shear failure or displacement of underlying materials. Because of accumulated distresses, the surface and base layers may no longer provide the structural capacity they once did—i.e., the layer coefficients of the distressed layers are less than when they were new. Thus, an overlay may be needed to restore the structural number of the pavement to its design level.[50] Moreover, a thicker-than-normal overlay can restore and add structural capacity to a roadway in the same project. The SN of a flexible pavement increases at a rate of .44 per inch of new asphalt-concrete surface layer.

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[48] Washington State Department of Transportation. *WSDOT Pavement Guide*. Volume 2: Pavement Notes For Design, Evaluation and Rehabilitation, February 1995. The incremental pavement analysis process used in this study is based largely on Chapter 7 of the *1995 WSDOT Pavement Guide* and the *1993 AASHTO Guide for the Design of Pavement Structures*.

[49] American Association of State Highway and Transportation Officials. *AASHTO Guide for Design of Pavement Structures*, 1993.

[50] A hypothetical pavement is used to illustrate the effects of accumulated distresses on pavements and the corrective benefits of an overlay. In this example, a new flexible pavement is designed with a 5-inch AC surface layer, an 8-inch bituminous-treated base, and a 10-inch subbase layer of crushed aggregate. Generally, each inch of asphalt-concrete surface adds .44 to the structural number of a pavement, while each inch of bituminous-treated base contributes .30 to the SN. Typically, the layer coefficient for an untreated base is .11. Based on these layer coefficients, the overall structural number of the new pavement is 5.7. However, according to pavement theory, its structural capacity diminishes with accumulated traffic loadings. When the AC surface layer exhibits more than 10 percent low-severity alligator cracking, combined with transverse cracking, its layer coefficient may drop to .30. Similarly, the layer coefficient of the stabilized base may drop to .18 as a result of accumulated stresses. In this example, the effective structural number of the aged pavement drops from 5.7 to 4.0. Approximately four inches of new AC surface are needed to restore the structural capacity of the pavement to its original design level.

Incremental versus pavement preservation costs

WSDOT's pavement preservation strategy envisions predictable growth in truck traffic during the life of a resurfacing improvement. However, the preservation strategy does **not** envision a sudden large percentage increase in truck traffic on low-volume roads with a history of modest truck traffic. The sudden shift of rail traffic to trucks after abandonment of 372 miles of PCC rail lines in eastern Washington could instantly double the annual truck traffic on some minor arterial and collector highways.

Analytical methods

The incremental thickness method of estimating highway costs uses the AASHTO pavement design equations. A similar approach was used in the Transportation Research Board's Special Report 225: *Truck Weight Limits*. The AASHTO equation for designing flexible pavements is:

Equation 1

$$\log_{10}\left(W_{18}\right) = 9.36 \times \log_{10}\left(SN+1\right) - .20 + \frac{\log_{10}\left(\Delta PSI/1.7\right)}{.40 + \frac{1{,}094}{\left(SN+1\right)^{5.19}}}$$
$$+ 2.32 \times \log_{10}\left(M_R\right) - 8.07$$

Where:

- W_{18} = Predicted number of 18-kip equivalent single-axle loads (ESALs)
- SN = Structural number
- PSI = Pavement serviceability index
- M_R = Resilient modulus of soil (psi)
- $\log_{10}$ = Common logarithm to the base 10

Once ΔPSI and resilient modulus are determined, the required structural number becomes a function of the design (projected) ESALs. However, this relationship is logarithmic. In a mathematical function where both the response variable (SN) and the causal variable (ESALs) are in log form, the coefficient of the causal variable is a measure of elasticity—e.g., it represents the percentage change in structural number for a one percent change in ESALs.

In TRB Special Report 225, this relationship was illustrated by graphing ESALs versus SN on log paper. A numerical (statistical) approach is used in this report. The relationship between SN and ESALs is simulated for a range of potential designs by incrementing the value of SN in the AASHTO pavement design equation by very small increments. This simulation creates a set of "observations" of structural numbers and corresponding ESALs. The log of ESALs is then regressed against the log of SN to determine the slope coefficient. The results of this analysis are shown in Table 12.

TRB Special Report 225 concluded that the slope coefficient is .015 when the SN ranges from 3 to 5, the terminal serviceability (PSI) is 2.7, and the resilient modulus is 6,250 psi.[51] The numerical approach yields the same slope estimate (.01535) for the same range and assumed terminal PSI and M_R. This coefficient is interpreted as the percentage change in structural number corresponding to a one percent change in ESALs. However, it is important to note that this coefficient is valid only for a limited range of structural numbers.

Table 12 shows a set of slope coefficients or *elasticities* for structural classes of pavements. A coefficient in Table 12 represents the percentage change in structural number corresponding to a one percent change in ESALs for a given structural class of pavement. The use of multiple coefficients allows economies of pavement thickness to be reflected in the incremental cost estimates. For example, the slope coefficient for light-duty flexible pavements is .178. This means that when a one percent increase in ESALs occurs on a light-duty flexible pavement, the structural number must be increased by .178 percent to maintain the same performance period. In comparison, a one percent increase in ESALs on a heavy flexible pavement section means that the structural number must be increased by .142 percent to maintain the same performance curve. The structural capacity of rigid or concrete pavements is represented by the slab thickness (D).

Table 12. Elasticity of Pavement Structural Number with ESALs

Structural Class	Flexible Pavement		Rigid Pavement	
	SN Range	Slope Coefficient	D Range	Slope Coefficient
Heavy	4.6 – 6.0	0.14204	9.1 – 14.0	0.14923
Medium	3.1 – 4.5	0.16700	7.1 – 9.0	0.16569
Light	1.0 – 3.0	0.17766	5.0 − 7.0	0.19510

[51] The estimated slope coefficient is not sensitive to variations in resilient modulus. However, it is sensitive to variations in terminal PSI. For purposes of this study, a terminal PSI of 3.0 is used. The WSDOT preservation program is intended to prevent the PSI from dropping below 3.0. Using this value, the estimated slope coefficient is 0.16886 for flexible pavements. For Portland cement concrete pavements, the estimated slope coefficient is 0.15750.

Key calculations

In order to implement this procedure, the current (design) ESALs and the current (design) structural number must be known for each impacted highway segment. Both inputs are derived from the WSPMS. The procedure is implemented as follows:

1. The percent increase in ESALs for an impacted segment is computed by dividing the ESALs generated from the potential abandonment by the existing ESALs and multiplying by 100.
2. The percent increase in structural number is computed from the appropriate slope coefficient in Table 12.
3. The numerical increase in structural number is computed by multiplying the design (current) SN by the percent increase divided by 100.
4. The increased overlay thickness is computed by dividing the increase in structural number by .44—the layer coefficient for new asphalt concrete.
5. The cost per inch is computed by dividing the appropriate paving unit cost in Table 7 by 1.8 (the median overlay depth) and multiplying the result by the number of affected lanes.
6. The incremental cost is computed by multiplying the cost per inch by the incremental inches of thickness.

Three important notes are needed to clarify this process:

1. It is assumed that WSDOT restores the diminished structural capacity of the roadway through its normalized preservation program so that the SN used in computing the incremental thickness is the current SN.
2. The incremental thickness is added at the time the pavement is scheduled for preservation resurfacing.
3. The incremental thickness is allowed to vary as a ratio-scaled variable—i.e., it is possible to increase the normal overlay thickness by fractions of an inch.

BST routes

Neither analytical method directly addresses the marginal or incremental cost of BST routes. BST segments are flexible pavements. However, they do not have AC surfaces. Older layers of asphalt concrete are usually found underneath the BST layers. In many cases, these AC base layers are resting upon treated or untreated bases that were laid when the highway was originally constructed. It is these layers that provide the BST segments with most of their structural capacity.

Because of large percentage increases in ESALs after abandonment, many BST routes will require structural AC overlays instead of surface treatments. In essence, they will need to be converted to AC pavements. In the average cost method, BST routes are overlaid with an asphalt-concrete surface layer. However, the thickness of the simulated overlay varies with the functional class. Some BST segments of US Highway 2 (US-2) are classified as Other Rural Principal Arterial. The marginal costs for these segments are based on an approximate 2-inch overlay. Some BST segments are classified as Rural Minor Arterial. The marginal costs for these segments are based on an approximate 1.25-inch overlay. Some BST segments are classified as Rural Major Collector. The marginal costs for these segments are based on an approximate 1-inch overlay. In the incremental method, all BST segments are converted to ACP segments assuming a standard overlay thickness of 1.8 inches.

These conversion costs for BST pavements represent short-run solutions. The short-run costs may be only the "tip of the iceberg." A significant increase in ESALs on BST segments may require WSDOT to reconstruct the route to ACP route standards. The pavement reconstruction cost involved in such a conversion would be two to three times the cost of a normal preservation overlay. Moreover, the route must be brought up to current design standards as specified in the *WSDOT Design Manual*. The full cost of a BST-to-ACP route conversion is $500,000 per lane-mile or $1 million per roadway mile.[52]

Estimated highway impacts

Post-abandonment scenarios

Some uncertainty exists regarding the distribution of traffic in a post-abandonment environment. Cost comparisons presented in the first interim report suggest that most of the traffic from the Coulee City line will move via the Ritzville shuttle-train facility—i.e., it will be trucked to Ritzville and shipped to Pacific Coast ports in 110-car trains. However, when shippers were asked about their post-abandonment decisions, they expressed uncertainty about the effects of the Ritzville subterminal. The decisive factor, they said, may be the reaction of barge operators to the facility and the rate competition that ensues between the BNSF and barges.[53]

[52] More than 270 miles of BST pavement would be affected by the potential abandonment. All of these route conversions could not possibly be accommodated within the existing preservation budget. The costs shown in this report assume that WSDOT will preserve the routes with structural overlays until additional funding can be obtained for full-scale conversion. Admittedly, these short-term costs may not adequately capture the true long-term effects. However, in this study, changes in highway costs and other benefits are computed for a 10-year period only. At present, costs or benefits that would occur more than 10 years into the future are not admissible under the governing federal benefit-cost guidelines.

[53] Trucks currently haul a significant amount of traffic from elevators on the Coulee City line to river ports. The truck-barge mode offers several advantages to shippers including: (1) familiarity (they use the service already), (2) capacity, and (3) economy (low rates).

Because of uncertainty, two post-abandonment scenarios are analyzed for the Coulee City line: (1) transshipment via Ritzville and (2) transshipment via Tri-Cities. It is possible that some stations located on the Marshall-Pullman line and the BLMR North will ship via Ritzville if these rail lines are abandoned. However, many of these stations are located near Central Ferry or Windust. The probabilities of these stations shipping north or west to Ritzville are quite low. Shippers located on the BLMR South are in close proximity to Central Ferry, Wallula, and the Tri-Cities. Unless there is a change in navigation conditions on the Snake-Columbia Waterway, the probabilities of these stations shipping northwest to Ritzville are extremely low.

Incremental truck trips

Table 13 shows rail carloads, tons, and equivalent trucks for each PCC subsystem, based on 2000 traffic levels. The equivalent trucks (Column 4) are computed by dividing the net truckload factors calculated earlier in Tables 3 through 6 into the rail tonnage (Column 3).[54] The average ratio of trucks to rail cars (Column 5) is computed by dividing the equivalent trucks into the rail carloads (Column 2).

Altogether, abandonment of the PCC system would increase annual truck trips by more than 29,000. Most of these incremental trips would be generated from the Cheney-to-Coulee City line and the BLMR North. Each of these subsystems would generate in excess of 10,000 new heavy truck trips per year.

If barges make a strong play for the traffic, the remaining question is: How badly does BNSF want to keep the traffic and how much downward pricing flexibility do they have?

[54] The equivalent trucks shown in Table 13 are based on average net tons per rail car as computed from the railroad waybill sample. These load factors reflect 2000 traffic and car types. The average load factor for farm products was 102 tons per car on the Coulee City line, 94 tons per car on the Marshall-to-Pullman line, and 99 tons per car on the BLMR. The lower load factor for the Marshall-to-Pullman line reflects some non-grain movements such as peas, lentils, and seeds. In the future, net car weights of farm products are expected to rise as the percentage of 286,000-pound cars increases. However, it is assumed that the total tons shipped will remain the same. Therefore, the total number of trucks generated from the potential abandonments should remain the same unless the mix of truck equipment is altered or the total tons shipped from the stations increases after abandonment.

Table 13. Rail Carloads and Potential Trucks Attributable to PCC Rail System				
Rail Subsystem	**Rail Carloads**	**Rail Tons**	**Equivalent Trucks**	**Truck/Rail Car Ratio**
BLMR North	3,447	340,371	10,083	2.9
BLMR South	1,336	88,997	2,977	2.2
Cheney-Coulee City	3,971	405,042	11,238	2.8
Marshall-Pullman	1,946	173,340	4,868	2.5
Total: PCC System	10,699	1,007,750	29,166	2.7

Percentage increase in ESALs

Table 14 shows the projected increase in ESALs for each type of pavement surface if the PCC rail lines are abandoned and the commodities are trucked to river ports. As Table 14 shows, the annual ESALs on 33 miles of BST pavement in eastern Washington would more than triple after abandonment.[55] The annual ESALs on another 46 miles of BST pavement would more than double after abandonment. Approximately 80 percent (or 219 miles) of all affected BST miles would experience more than a 10 percent increase in annual ESALs. In addition, more than half of the 355 ACP miles included in truck routes to the river would experience more than a 5 percent increase in annual ESALs.

[55] Table 14 reinforces the fact that BST routes in eastern Washington are designed as low-volume, low-ESAL routes. At present, most of them have low truck traffic levels.

Table 14. Projected Increase in ESALs by Type of Pavement Surface			
	Miles of Roadway		
Percent Increase in Annual ESALs	**BST**	**ACP**	**Portland Cement Concrete**
≤5	33.1	154.2	.
>5 and ≤10	19.8	74.4	8.4
>10 and ≤25	60.2	46.9	10
>25 and ≤50	30.4	31.8	.
>50 and ≤75	19.7	37	.
>75 and ≤100	29.1	8.4	.
>100 and ≤200	46.4	0.9	.
>200 and ≤300	33.1	0.4	.
>300	0.2	0.5	.

These are computed values.

Table 15 shows another dimension of the situation. Nearly 95 percent of the miles of Rural Major Collector highway included in truck routes from PCC stations to river ports would experience at least a 10 percent increase in ESALs if the rail lines are abandoned. Moreover, 82 percent of the affected Rural Minor Arterial highway miles would experience at least a 10 percent increase in annual ESALs. The annual ESALs would more than double on 82 miles of rural collector highway.

Table 15. Projected Increase in ESALs by Functional Class of Rural Highway			
	Miles of Roadway		
Percent Increase in Annual ESALs	**Rural Other Principal Arterial**	**Rural Minor Arterial**	**Rural Major Collector**
≤5	133.5	8.0	5.9
>5 and ≤10	77.9	13.7	5.6
>10 and ≤25	31.5	57.6	21.4
>25 and ≤50	8.2	40.0	13.9
>50 and ≤75	29.0	.	27.7
>75 and ≤100	7.6	.	30.0
>100 and ≤200	.	.	47.3
>200 and ≤300	.	.	33.6
>300	.	.	0.7

Impacts of truck movements to river ports

Results of average/marginal cost approach

The estimated annual changes in pavement cost resulting from the potential abandonment of parts of the PCC system are shown in Table 16. Column 2 of Table 16 shows the additional annual cost and user fees resulting from the incremental truck trips.[56] Tables 17-20 show the impacts of these potential movements for each railroad subsystem and route.

Table 16. Annual Pavement Cost Resulting from Potential Abandonment of PCC Railroad Lines

Main Scenario: Transshipment via River Ports

	Thousands of Dollars per Year		
Rail Subsystem	**Change in Resurfacing Cost**	**Change in Truck User Fees**	**Net Change in Highway Cost**
BLMR North	$605	$153	$452
BLMR South	$479	$40	$439
Cheney-Coulee City	$4,040	$397	$3,643
Marshall-Pullman	$393	$105	$288
Total: PCC System	**$5,517**	**$695**	**$4,822**

[56] The user fees include motor fuel tax revenues, vehicle registration fees, excise taxes, and heavy vehicle use fees. For the Rocky Mountain Doubles, these user fees amount to roughly 16 cents per vehicle-mile. The user fee per-mile is relatively high for these trucks because they accumulate only 60,000 to 75,000 annual miles. The vehicle registration fees, excise taxes, and heavy vehicle use fees are higher per mile for these trucks than for commercial trucks with higher utilization rates. The user fees per mile are slightly lower for other truck classes, such as the combination 5-axle truck.

Table 17. Annual Pavement Cost Resulting from Potential Abandonment of Cheney-to-Coulee City Rail Line			
Main Scenario: Transshipment via River Ports			
	Thousands of Dollars per Year		
Route	**Annual Change in Resurfacing Cost**	**Annual Change in Truck User Fees**	**Net Change in Highway Cost**
2	$74.20	$20.60	$53.70
17	$1,039.50	$93.70	$945.80
21	$2,576.00	$199.60	$2,376.30
28	$134.40	$11.00	$123.40
90	$13.50	$8.60	$4.90
182	$0.80	$1.00	($0.20)
231	$63.70	$9.80	$53.90
263	$94.90	$23.50	$71.40
395	$43.40	$29.50	$13.90
Total	**$4,040.40**	**$397.20**	**$3,643.20**

Table 18. Annual Pavement Cost Resulting from Potential Abandonment of Marshall-to-Palouse Rail Line			
Main Scenario: Transshipment via River Ports			
	Thousands of Dollars per Year		
Route	**Annual Change in Resurfacing Cost**	**Annual Change in Truck User Fees**	**Net Change in Highway Cost**
26	$168.80	$25.70	$143.10
27	$55.00	$7.60	$47.40
127	$59.50	$26.00	$33.50
195	$74.00	$41.10	$32.90
270	$3.40	$1.60	$1.80
271	$7.20	$0.80	$6.40
272	$24.90	$2.20	$22.70
Total	**$392.80**	**$105.00**	**$287.80**

Table 19. Annual Pavement Cost Resulting from Potential Abandonment of BLMR- North			
Main Scenario: Transshipment via River Ports			
	Thousands of Dollars per Year		
Route	Annual Change in Resurfacing Cost	Annual Change in Truck User Fees	Net Change in Highway Cost
23	$155.20	$15.80	$139.40
26	$267.90	$43.20	$224.70
127	$117.60	$52.80	$64.80
195	$53.30	$34.90	$18.40
270	$11.10	$6.20	$4.80
Total	**$605.10**	**$152.90**	**$452.20**

Table 20. Annual Pavement Cost Resulting from Potential Abandonment of BLMR- South			
Main Scenario: Transshipment via River Ports			
	Thousands of Dollars per Year		
Route	Annual Change in Resurfacing Cost	Annual Change in Truck User Fees	Net Change in Highway Cost
12	$63.30	$17.30	$46.00
124	$416.00	$23.00	$392.90
Total	$479.30	$40.40	$438.90

Results of incremental thickness method

Table 21 summarizes the estimated pavement costs for each railroad subsystem using the incremental pavement thickness method. Column 2 of Table 21 shows the estimated cost in nominal dollars while Column 3 shows the present values of the estimates.[57]

[57] These present values reflect a real discount rate of 4.33 percent. This is the rate prescribed by the Federal Railroad Administration for estimating the benefits of rail-line improvements.

Table 21. Incremental Pavement Cost Resulting from Potential Abandonment of PCC Railroad Lines		
Main Scenario: Transshipment via River Ports		
Rail Subsystem	**Thousands of Dollars**	
	Future Cost	**Present Value**
BLMR North	$6,505	$5,701
BLMR South	$3,556	$3,074
Cheney-Coulee City	$34,141	$31,045
Marshall-Pullman	$6,332	$5,582
Total: PCC System	**$50,534**	**$45,402**

The estimates shown in Table 21 are based on future resurfacing events for each individual WSPMS segment. Resurfacing is assumed to occur in the year the pavement is due, as shown in the WSPMS database. Pavements listed as past due or due in 2001 are assumed to be resurfaced immediately—e.g., at time zero. For all other due years, the estimated incremental resurfacing cost is discounted to present value.

In a few cases, the due year for the WSPMS segment is more than ten years in the future. Under federal benefit-cost guidelines, ten years is the maximum time frame that can be considered for future benefits. Table 22 shows the forecasted incremental resurfacing costs for ten years only. As a comparison of Tables 21 and 22 shows, the vast majority of resurfacing events are expected to occur within the 10-year benefit-cost period.[58]

Table 22. 10-Year Incremental Pavement Cost Resulting from Potential Abandonment of PCC Railroad Lines		
Main Scenario: Transshipment via River Ports		
Rail Subsystem	**Thousands of Dollars**	
	Future Cost	**Present Value**
BLMR South	$6,222	$5,619
BLMR North	$3,549	$3,071
Cheney-Coulee City	$31,890	$29,735
Marshall-Pullman	$5,965	$5,412
Total: PCC System	**$47,627**	**$43,838**

With this revision, it is now possible to compare incremental pavement costs and incremental truck revenues generated from user fees. The

[58] This outcome was expected, given that the average life of resurfacing events in eastern Washington is 11 years.

present value of the annual truck revenues shown in Table 16 is $5.5 million for the 10-year analysis period. After these revenues are considered, the net present value of the resurfacing cost drops to $38.3 million.

As shown in Table 16, the annual pavement cost estimate derived from the average/marginal cost method is approximately $5.52 million. The present value of this cost for a 10-year period is $44 million. Thus, the net present value of the resurfacing costs estimated via this method is approximately $38.5 million. In this case, the pavement cost estimates derived from the two analytical approaches are quite similar.[59]

Transshipment via Ritzville

As noted earlier, it is potentially feasible for some elevators to transship via Ritzville if the PPC rail lines are abandoned. Table 23 shows the estimated annual pavement costs for two of the PCC's subsystems.

Table 23. Annual Marginal Pavement Cost Resulting from Potential Abandonment of PCC Subsystems

Contingent Scenario: Transshipment via Ritzville

	Thousands of Dollars per Year		
Rail Subsystem	**Change in Resurfacing Cost**	**Change in Truck User Fees**	**Net Change in Highway Cost**
Cheney-Coulee City	$2,363	$279	$2,084
Marshall-Pullman	$1,990	$125	$1,865

There is a moderate-to-high probability that the elevators located on the Coulee City line will find it more economical to sell their wheat at Ritzville than in traditional markets. However, the elevator and grower associations may be reluctant to do so. They would relinquish much of their marketing discretion. Many of these entities have policies of not consigning all of their freight to one mode or becoming captive to a single market. Many of them operate their own truck fleets and have unused truck capacity. Thus, the additional trucking distance to river ports may be less important to them than maintaining multiple shipping options and being able to sell directly into export markets.

[59] Table 8 provides some insights as to why the two methods produce almost identical results. The marginal costs per ESAL are nearly identical for rural minor arterial and collector highways. Most of the estimated impacts from the potential rail-line abandonments are attributable to rural minor arterial and collector segments. The key assumption that marginal cost is equal to average cost is especially appropriate in this case.

There is a much lower probability that elevators located on the Marshall-to-Pullman line will find it more economical to sell their wheat at Ritzville than in traditional markets. This line segment includes traffic originated from Palouse to Marshall. However, it includes some non-grain traffic.[60] Table 23 illustrates the difference in pavement impacts that would result if **all** traffic from Palouse to Marshall is transshipped via Ritzville. As a comparison of Tables 16 and 23 shows, the highway impacts would be much greater if the traffic on this line is trucked longer distances to Ritzville instead of moving to river ports.

Although the feasibility of transshipment via Ritzville is low for elevators located on the Marshall-to-Pullman line, the feasibility would increase if navigation is curtailed on the Snake River and the ports of Almota, Central Ferry, and Windust are closed. Similarly, the feasibility of movements to Ritzville from elevators located on the BLMR would increase if the Snake River was closed to navigation.

Build-sooner costs

The incremental thickness method assumes that WSDOT resurfaces the pavement in the due year and restores the lost structural capacity resulting from normal traffic and environmental deterioration. In actuality, large increases in truck traffic on BST or low-capacity segments may shift the due date forward in time. This phenomenon is called "Build-Sooner Cost." WSDOT must place the preservation overlay earlier than planned.

Because of the time value of money, there is a cost associated with earlier resurfacing, even if the paving depth and cost are the same. This cost is illustrated in Table 24, which shows the present value of the average preservation cost for rural two-lane highways in eastern Washington ($208,000 per mile).[61] If a preservation event for this type of highway is moved forward from Year 7 to Year 4 because of a large unexpected increase in truck traffic, the build-sooner cost would amount to $21,000.

[60] The coal traffic terminated at Pullman is assigned to the BLMR South. However, there is a small quantity of non-grain traffic originated from this line—e.g., peas, lentils, and seeds. It is unlikely that these commodities would be transshipped through Ritzville.
[61] This value is derived from the lane-mile cost shown in Table 7.

Table 24. Present Value of Preservation Cost for Rural Two-Lane Highway in Eastern Washington	
Future Year	**Present Value of Cost**
1	$199,367
2	$191,093
3	$183,162
4	$175,560
5	$168,274
6	$161,290
7	$154,596
8	$148,180
9	$142,030
10	$136,135

Analytically, these effects are very difficult to model. The method used in this study is based on the HERS pavement deterioration equations detailed in the Appendix A. The HERS flexible pavement deterioration equation is derived from the AASHTO pavement design equation (Equation 1).

To make the derivation easier to follow, Equation 1 is separated into major terms. The term *XB* describes the rate at which a pavement's structural life is consumed with the accumulation of ESALs. In Equation 3, *XB* is a function of the structural number as reflected in the term *SNA* of Equation 2.[62]

Equation 2

$$\mathrm{SNA} = \mathrm{SN} + \sqrt{\frac{6}{\mathrm{SN}}}$$

Equation 3

$$\mathrm{XB} = 0.4 + \left(\frac{1{,}094}{\mathrm{SNA}}\right)^{5.19}$$

XG depicts pavement serviceability loss in terms of the maximum tolerable decline in pavement serviceability rating (PSR) from an initial

[62] Equation 2 illustrates the main difference between the HERS pavement deterioration equations and the AASHTO design equations. The term SN + 1 in the AASHTO equation has been replaced with the term SN + $(6/\mathrm{SN})^{.5}$.

value after rehabilitation (P_I) to a terminal value at which the pavement is rehabilitated (P_T). The PSR and PSI range from 0 to 5. WSDOT uses an initial value (P_I) of 4.5 for new, reconstructed, or resurfaced pavements and a terminal value (P_T) of 3.0.

Equation 4

$$XG = \log_{10}\left(\frac{P_I - P_T}{3.5}\right)$$

The final term XA is also a function of SN. In this derivation, resilient modulus is assumed to be a constant mid-range value.

Equation 5

$$XA = 9.36\ \log_{10}(SNA) - 0.2$$

For purposes of this analysis, the Pavement Structural Condition (PSC) for the segment, as coded on the WSPMS record, is converted to PSR using the following formula:

Equation 6

$$PSR = 4.5 - (100 - PSC) \times .03$$

Manipulation of Equations 2 through 5 yields a predictive equation for PSR at the end of a period (PSR_f) based on the ESAL load during the period:

Equation 7

$$PSR_f = 5 - 3.5 \times 10^{XP}$$

The term XP is computed from XA and XB as follows:

Equation 8

$$XP = XB - (\log_{10}(ESALs) - XA)$$

The term ESALs in Equation 8 represents the accumulated ESALs during a time period (e.g., 1 year). Equation 8 is calculated until PSR_f is less than or equal to 3.0. In each iteration, PSR_f from the previous iteration becomes the PSR value at the beginning of the period. In essence, Equation 8 forecasts the decline in PSR for a highway segment each year starting from its current value. Thus, the number of years can be predicted before the PSR declines to its due threshold value (3.0).

The addition of ESALs to the baseline traffic, as a result of the potential rail-line abandonment, will cause a PSR value to decline more in a given year thereby shortening the time interval until rehabilitation. The results of the build-sooner cost analysis are shown in the Appendix B. Altogether, $1.1 million in build-sooner cost is estimated for the potentially-impacted highway segments.

Table 25 illustrates the results of the analysis for some of the impacted segments of SR-21. In many cases, the predicted year at which the pavement is due for resurfacing is the same as the due year shown in the WSPMS. However, in some cases the predicted due year is greater than the value shown in the WSPMS. This difference is the result of non-load deterioration that is not accounted for in Equation 7. Nevertheless, Equation 7 predicts the number of years that the resurfacing interval will be shortened by incremental ESALs, with all other factors held constant.

Table 25. Estimated Build-Sooner Costs as a Result of Potential PCC System Abandonment for Segments of SR-21

Beginning Milepost	Ending Milepost	PSR	Year Due: WSPMS	Predicted Year: Base	Predicted Year: Impact	Difference in Present Value of Cost
24.20	24.37	4.5	2014	2014	2008	$6,157
24.37	24.45	4.5	2014	2014	2007	$3,456
26.49	26.60	4.0	2006	2006	2003	$2,619
26.60	26.75	3.8	2005	2005	2002	$3,726
55.83	55.90	3.7	2005	2005	2002	$1,739
55.90	55.96	3.7	2005	2005	2002	$1,490
55.96	56.03	3.7	2005	2005	2002	$1,739
56.03	56.15	3.6	2004	2004	2002	$2,029
56.15	56.27	3.8	2005	2005	2002	$2,981
56.27	56.36	4.1	2007	2007	2003	$2,798
91.35	91.72	4.3	2009	2009	2007	$5,061

Build-sooner costs are an attempt to quantify the time-related effects of accelerated pavement preservation. In theory, they can be added to the cost of the incremental overlay thickness required to restore a pavement to its pre-abandonment performance period. However, the estimated costs shown in the Appendix B must be qualified. They depend on very precise forecasts of decline in roadway condition on a year-to-year basis—with and without the incremental truck traffic. It is doubtful that these estimates have the same level of precision as the incremental overlay costs presented earlier. Moreover, build-sooner costs ignore budgetary constraints and political realities. These estimates assume WSDOT has unlimited budget and resources so that it can respond immediately to the shortened resurfacing interval and move the impacted segment forward in the preservation improvement program.

Theoretically, it is possible for WSDOT to move an impacted highway segment forward in its long-term preservation improvement program. In practice, this is extremely difficult to do. Approximately 23 percent of state highway miles are past due for resurfacing. Moving impacted segments forward in the preservation improvement program means that other projects must be delayed, downgraded, or foregone. The build-sooner estimates assume that the segments impacted by abandonment are vaulted over segments in the queue or that the preservation budget is perfectly elastic. Neither of these assumptions is very realistic.

In the most likely scenario, many of the impacted pavement segments will become "past due"—i.e., the PSC will drop below 50 before WSDOT can apply preservation overlays. These segments will be rehabilitated in the due year as planned. However, the normal preservation cost will be greater. As shown in Table 8, the paving cost of a project that is less than three years past due is 25 percent greater than the paving cost of the same project when it is due. Moreover, the paving cost of a project that is three to six years past due is 50 percent greater than the timely cost of the same project.[63]

Past-due costs

The past-due cost estimates shown in the Appendix B assume that the pavement receives a preservation overlay in the future year for which it is predicted in the WSPMS. However, by the time the due year is reached, the pavement will be past due because of incremental traffic—in other words, the pavement has deteriorated faster that expected. Therefore, it should have been resurfaced earlier to achieve the optimal overlay cost. However, with a fixed preservation budget and a queue of past-due projects, the impacted segment could not be moved forward in the preservation program.

Build-sooner cost envisions normal resurfacing cost incurred at an earlier time. In contrast, past-due cost reflects a normal resurfacing interval, but a more deteriorated pavement at the end of the interval. According to

[63] As noted earlier, the paving cost of a rural two-lane highway in eastern Washington that is due for resurfacing is $96,500 per lane-mile or $193,000 per centerline mile. This value is simply the paving cost exclusive of safety-related and drainage work. Thus, letting a project slip two years past due means an additional $48,000 in paving cost. The difference in present value is approximately $28,000.

historic data, the paving cost of a project that is less than three years past due is 25 percent greater than the paving cost of the same project when it is due. Moreover, the paving cost of a project that is three to six years past due is 50 percent greater than the timely cost of the same project.

Table 26 illustrates estimated past-due costs for some impacted segments of SR-21. The past-due cost is computed from the percentage increases shown in Table 8. These costs include paving cost only. Safety and drainage restoration costs are not considered.

Table 26. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC Abandonment for Segments of SR-21

Beginning Milepost	Ending Milepost	Year Due: WSPMS	Years Past Due	Present Value of Future Cost
24.50	24.74	2012	> 6	$30,316
26.49	26.60	2006	3 to 6	$8,959
26.60	26.75	2005	3 to 6	$12,746
55.83	55.90	2005	3 to 6	$5,948
55.90	55.96	2005	3 to 6	$5,099
55.96	56.03	2005	3 to 6	$5,948
56.03	56.15	2004	3 to 6	$10,639
56.15	56.27	2005	3 to 6	$10,197
56.27	56.36	2007	3 to 6	$7,026
91.35	91.72	2009	< 3	$13,269
91.72	91.73	2011	< 3	$329
91.73	91.78	2011	< 3	$1,647

As shown in Appendix B past-due costs are projected to increase by nearly $14.7 million if the PCC rail network is abandoned. These costs result from accelerated deterioration of pavements and accumulated distresses as a result of incremental truck traffic. They are distinct from the incremental costs computed using the incremental thickness method. In the latter instance, incremental thickness is needed to increase the future structural capacity of the pavement in light of the permanent increase in heavy truck traffic. In the first instance, the thicker overlay is needed to restore the pavement to its design structural capacity given the higher severity of fatigue cracking and other distresses that have developed during the current resurfacing interval.[64]

Past-due and build-sooner costs cannot be added together. One cost or the other will be incurred during the present resurfacing interval if the rail lines are abandoned. These cost estimates should be interpreted in light of

[64] A greater severity of fatigue cracking reduces the structural coefficient of the current AC layer as a base layer and thus increases the need for a thicker overlay.

current WSDOT policy, highway needs, budgetary resources, and political constraints.

Truck tire factors

The AASHTO axle-load equivalency formulas are based on road test data from the 1960s, which reflects the use of dual bias (ply) tires with pressures of 75 to 80 pounds per square inch (psi). Today, most commercial trucks use radial tires inflated to 100 psi or greater. In some cases, *super-single* tires are used instead of dual tires.

A higher tire inflation pressure reduces the contact area of the tire with the pavement and increases the surface stress of a given wheel load. Simulations by Gillespie (1993) suggest that increasing tire inflation pressure from 75 to 110 psi increases fatigue damage of flexible pavements by 200 percent.[65] In Special Report 225, TRB (1990) cited the results of several studies, which show that increasing tire inflation pressure from 75 to 110 psi increases the ESAL factor of an 18,000-pound single axle from 1.0 to 1.2.[66] The TRB also says that increasing tire pressure from 75 to 100 psi increases the ESAL factor of an 18,000-pound single axle from 1.0 to 1.15. Research also suggests that using single tires instead of dual tires can increase the pavement impact of an 18,000-pound single axle load by 31 to 123 percent.[67]

In short, the use of super-single tires and high inflation pressures result in much greater reductions in pavement lives than the AASHTO ESAL factors suggest. Therefore, the costs presented in this report may understate the pavement-related effects of modern truck tires. This understatement may be particularly significant on low-ESAL roads. Doubling or tripling the annual truck trips on these roads may increase the annual ESALs in much greater proportions.[68]

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[65] Gillespie, T.G., S.M. Karamihas, M. W. Sayers, M. A. Nasim, W. Hansen, and N. Ehsan. *Effects of Heavy-Vehicle Characteristics on Pavement Response and Performance,* NCHRP Report 353, National Academy Press, 1993. This simulation is for a set of 11R22.5 dual tires mounted on a single axle loaded to 20,000 pounds, traveling over a 5-inch AC wear course. For details, see Figure 44 of this reference.
[66] Transportation Research Board (TRB), *Truck Weight Limits*, Special Report 225, 1990.
[67] Transportation Research Board (TRB), *Truck Weight Limits*, Special Report 225, 1990. The range of impacts depends on the “wander” or lateral movement of truck tires. Wander has a positive effect on pavement life for a given axle load and tire because the load is not concentrated on a linear path or area of pavement. The 31 percent increase corresponds to a wander standard deviation of 8 inches, while the 132 percent increase corresponds to zero wander.
[68] An adjustment to ESAL factors to account for modern tire inflation pressures would be justified in this chapter. However, the costs calculated using the incremental thickness method are based on percentage increases in ESALs. As long as the baseline ESALs and incremental ESALs are calculated in a consistent manner, an adjustment for tire pressure should have little effect on the results.

Conclusion

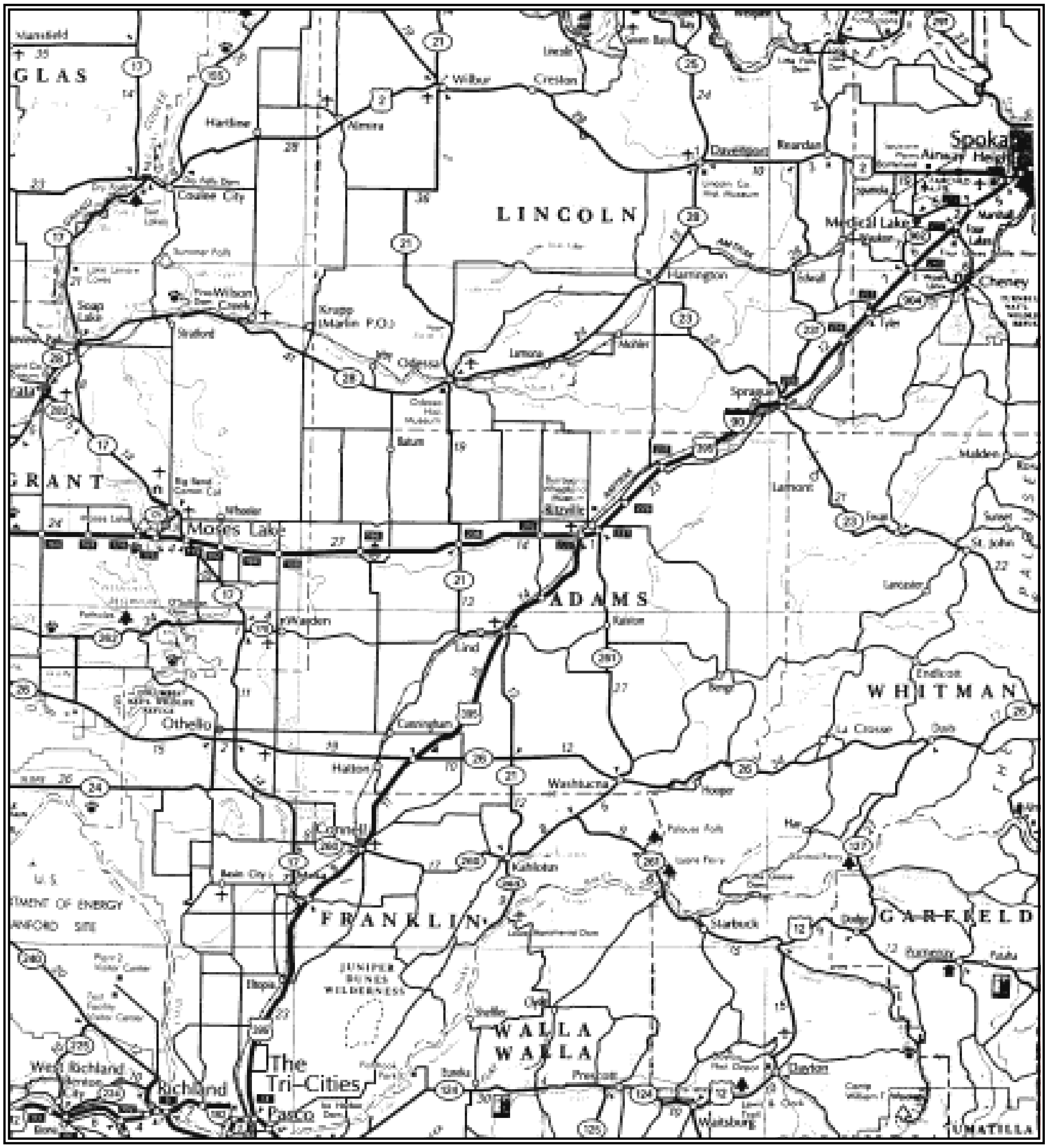
Abandonment of the Palouse River and Coulee City Railroad would increase heavy truck traffic in eastern Washington by more than 29,000 trips per year. In the most likely scenario, most of these trucks would move to river ports. Many of the north-south routes in eastern Washington include BST or ACP segments with lower structural numbers. Many of these same segments are collector or minor arterial highways that are not designed for the magnitude of heavy truck traffic that would result from the abandonment. State Routes 21 and 17 would be impacted most heavily.

In the current preservation cycle, WSDOT would incur build-sooner or past-due costs because of the accelerated deterioration of pavements as a result of large percentage increases in ESALs. These costs could range from \$1.1 to \$14.7 million depending on the ability of WSDOT to find supplemental highway funds to move the impacted segments forward in the pavement preservation program. In the most likely scenario, the impacted pavements will become past due and the \$14.7 million cost will be incurred. However, this cost only restores the pavement to its normal structural capacity. Additional structural capacity will be needed to keep the pavement from continuing its accelerated rate of deterioration in future periods. The logical time to add this capacity is at the scheduled time for a preservation overlay. If this occurs, the additional cost (in addition to the past-due or build-sooner cost incurred in the current resurfacing period) will be the cost of additional pavement thickness needed to provide the increased structural number necessary to accommodate the permanent increase in truck traffic.

Over a 10-year period, the estimated present value of this cost is \$43.8 million. However, the incremental pavement cost is offset partially by incremental truck user fees of \$5.5 million. Thus, the estimated net present value of this cost is \$38.3 million. However, if the present value of potential past-due cost is considered, the pavement cost resulting from abandonment of PCC's rail lines in eastern Washington could exceed \$50 million. Even this estimate doesn't fully capture the future costs associated with converting BST to ACP routes. In outlying years, this hidden cost could be substantial.

Washington State
Department of Transportation

Appendix A. Map of Coulee City Line Region and Highway Access to Tri-Cities



Appendix B. Regional Soil Characteristics

The native soils in eastern Washington are quite diverse. In many areas, soils have been formed by glacial, fluvial, and wind actions. Frequently, soils in these areas are formed in sandy or silty eolian materials on top of glaciofluvial sediments. The subsoils tend to have low water-holding capabilities. When saturated, these soft silt-like materials tend to flow laterally under load. In essence, areas of the subgrade may be “squeezed out” by heavy axle loads and sags and depressions may result in the track.

The segment of the Cheney-to-Coulee City line between Hartline and Coulee City is a primary concern. Apparently, BNSF—the former owner—embargoed sections of the line periodically. Table B.1 summarizes the characteristics of soils found along this line segment.

Table B.1 Soil Characteristics of Coulee City Line Basin

Line Segment	Primary Soil Type	Soil Description
Cheney-to-Davenport	L4	Fine-silty loessial soils. Humus-rich top soil. Subsoil accumulations of lime and/or clay.
Davenport-to-Creston	X3	Complex landscape patterns. Soils formed in loess over flood-scoured basalt mixed with soils formed in loess over silty, sandy, or cobbly flood sediment.
Creston-to-Wilbur	L3	Coarse-silty loessial soils with lime at a depth of 44"-70".
Wilbur-to-Almira	X3	Complex landscape patterns. Soils formed in loess over flood-scoured basalt mixed with soils formed in loess over silty, sandy, or cobbly flood sediment.
Almira-to-Hartline	L2	Dry coarse-silty loessial soils with lime at a depth of 30"-43"
Hartline-to-Coulee City	De2	Dry soils formed in sandy or silty eolian materials over glaciofluvial sediments. Most have low water holding capabilities.

Appendix C. Train Resistance Formulas

As noted in Chapter 1, train resistance is measured in pounds per ton. It reflects many forces such as: (1) rolling resistance, (2) flange resistance, (3) journal (axle) resistance, (4) track resistance, (5) air resistance, and (6) curve resistance. Over the years, many tests have shown that train resistance can be determined from the following expression:[1]

$$R = A + BV + CDV^2$$

where:

R = train resistance in pounds per ton
A = rolling resistance component
B = coefficient that defines speed-dependent resistance
C = streamlining coefficient used to define resistance that varies with the square of speed
D = aerodynamic coefficient
V = train speed in mph

The Davis Formula is an empirically derived equation of the form:

$$R = 1.3 + \frac{29}{W} + .045V + \frac{.0005aV^2}{WN}$$

where:

R = train resistance in lb/ton
W = axle weight of a locomotive or car (in tons)
N = number of axles
a = cross-sectional area of a locomotive or car (in square-feet)

The Davis Formula is often adjusted to reflect modern axle types and car dimensions. The results obtained from applying the original formula can be multiplied by a K-factor of .85 to better represent modern equipment and operating characteristics (Hay, 2000).

Table C.1 illustrates the calculation of a train resistance factor for a covered hopper car at an assumed grade speed of 14 mph. This factor was used in the report to compute a tonnage rating for a 2,250-hp locomotive.

[1] American Railway Engineering and Maintenance of Way Association. *Manual for Railway Engineering*, 2000.

Table C.1 Use of Davis Formula to Compute Train Resistance Factor for Covered Hopper Car	
Gross car weight	134.5
w	33.63
n	4
V	14
V^2	196
A	125
b	0.045
C	0.0005
CAV^2	12.25
wn	134.5
Unadjusted result	2.88
K-factor	0.85
Adjusted result	2.45

Appendix D. Western Region Worktable E

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WORKTABLE E1 PART 1 Annual URCS Process for Region 7 - West 19-Dec-01

OUTPUT UNIT COSTS

UNIT COSTS FOR LINEHAUL, TERMINAL, CLERICAL AND SPECIAL SERVICE OPERATIONS

LINE	SERVICE UNIT	OPR EXPENSE UNIT COST (1)	DRL EXPENSE UNIT COST (2)	ROI EXPENSE UNIT COST (3)
101	GROSS TON MILE	0.00125764	0.00051208	0.00099557
102	CAR MILE-OTHER THAN CLERICAL	0	0	0
103	TRAIN MILE-OTHER THAN CREW	0.58564	0.00448	0.00432
104	TRAIN MILE-CREW	6.81391	XXXX	XXXX
105	LOCOMOTIVE UNIT MILE	2.0657	0.4294	0.3443
106	CLOR (CARLOADS HANDLED)-OTHER	2.7879	0.0000	0.0000
107	CLOR (CARLOADS HANDLED)-CLERICAL	0	XXXX	XXXX
108	CL ORIG OR TERMINATED-OTHER	0.00000	XXXX	XXXX
109	CL ORIG OR TERMINATED-CLERICAL	10.45490	XXXX	XXXX
110	CAR MILE-CLERICAL	0	XXXX	XXXX
111	SWITCH ENGINE MINUTES	3.5547	0.3708	1.3571
112	TON MILES IN LAKE TRANSFER SERVICE	0.0000	0.0000	0.0000
113	TONS HANDLED AT COAL TERMINALS	0.50849801	0.00000000	0.00000000
114	TONS HANDLED AT ORE TERMINALS	1.48691	0.01613	0.06649
115	TONS HANDLED AT OTHER MARINE TERMINALS	34.4156	0.0000	0.0000
116	REFRIGERATED CAR MILES	0.09827	XXXX	XXXX
117	PROTECTIVE SERVICE REEFER TCU DAYS	0.30093801	XXXX	XXXX
118	REFRIGERATED TCU DAYS	0.06828	0.01372	0.00154
119	OTHER (NON-REFRIGERATED) TCU DAYS	4.78904	6.46595	0.13049
120	TCU'S LOADED AND UNLOADED	29.07210	1.13881	2.63002
121	MVU'S LOADED AND UNLOADED	5.89509	XXXX	XXXX
122	TCU'S PICKED UP AND DELIVERED	112.36600	XXXX	XXXX

WORKTABLE E1 PART 2 Annual URCS Process for Region 7 - West 19-Dec-01

OUTPUT UNIT COSTS

UNIT COSTS FOR FREIGHT CAR OWNERSHIP AND MAINTENANCE

LINE	CAR TYPE	OPR EXPENSE UNIT COST CM(R) RR OWNED (1)	DRL EXPENSE UNIT COST CM(R) RR OWNED (2)	ROI EXPENSE UNIT COST CM(R) RR OWNED (3)	OPR EXPENSE UNIT COST CM(Y) RR OWNED (4)
201	BOX - 40 FOOT GENERAL	0.02829	0.11438	0.05225	0.07356
202	BOX - 50 FOOT GENERAL	0.02829	0.11438	0.05225	0.07356
203	BOX - EQUIPPED	0.02086	0.03524	0.01125	0.05423
204	GONDOLA PLAIN	0.01693	0.01154	0.01221	0.04401
205	GONDOLA - EQUIPPED	0.03048	0.02991	0.01389	0.07925
206	HOPPER - COVERED	0.02511	0.00536	0.01915	0.06528
207	HOPPER - OT - GENERAL	0.01388	0.00951	0.01669	0.03610
208	HOPPER - OT - SPECIAL	0.01664	0.00572	0.00917	0.04327
209	REFRIGERATOR - MECH.	0.02066	-0.02271	0.01833	0.05371
210	REFRIGERATOR - NON. MECH.	0.01590	0.01992	0.02956	0.04134
211	FLAT - TOFC	0.00000	0.19112	0.00000	0.00000
212	FLAT - MULTILEVEL	0.00000	0.14515	0.00000	0.00000
213	FLAT - GENERAL	0.04590	0.03965	0.03537	0.11933
214	FLAT - OTHER	0.01790	0.04735	0.01399	0.04655
215	TANK <22,000 GAL	0.00000	0.06429	0.00000	0.00000
216	TANK >=22,000 GAL	0.00000	0.06039	0.00000	0.00000
217	ALL OTHER FC	0.10943	0.00472	0.00865	0.28451
218	AUTO RACKS	0.00000	0.02728	0.00000	0.00000
219	ACCESSORIAL	0.00000	0.00020	0.00006	0.00000
220	AVERAGE FC	0.02431	0.01892	0.01569	0.09376
221	TOTAL FLAT, MULTILEVEL	0.00000	0.14515	0.00000	0.00000

OUTPUT UNIT COSTS
UNIT COSTS FOR FREIGHT CAR OWNERSHIP AND MAINTENANCE

LINE	DRL EXPENSE UNIT COST CM(Y) RR OWNED (5)	ROI EXPENSE UNIT COST CM(Y) RR OWNED (6)	OPR EXPENSE UNIT COST CD(R) RR OWNED (7)	DRL EXPENSE UNIT COST CD(R) RR OWNED (8)	ROI EXPENSE UNIT COST CD(R) RR OWNED (9)
201	0.29740	0.13585	3.66386	50.14510	10.03440
202	0.29740	0.13585	3.66386	50.14510	10.03440
203	0.09162	0.02925	2.58752	12.12740	2.06242
204	0.03000	0.03173	1.96312	8.31359	2.20731
205	0.07777	0.03613	2.76424	7.94683	1.87014
206	0.01393	0.04978	2.65224	9.38993	3.02453
207	0.02473	0.04340	1.39649	2.25137	2.51716
208	0.01487	0.02385	1.21673	8.16404	1.02842
209	-0.05905	0.04766	3.09884	6.01758	4.15146
210	0.05180	0.07685	2.01735	7.10367	5.49391
211	0.00000	0.00000	0.00000	0.00000	0.00000
212	0.00000	0.00000	0.00000	0.00000	0.00000
213	0.10308	0.09197	5.58324	16.94470	6.66582
214	0.12310	0.03636	2.10585	13.40820	2.44880
215	0.00000	0.00000	0.00000	0.00000	0.00000
216	0.00000	0.00000	0.00000	0.00000	0.00000
217	0.01227	0.02248	7.11993	1.86983	0.90426
218	0.00000	0.00000	0.00000	0.00000	0.00000
219	0.00053	0.00014	0.00005	0.04193	0.00656
220	0.05912	0.05521	2.46978	9.98483	2.38299
221	0.00000	0.00000	0.00000	0.00000	0.00000

WORKTABLE E1 PART 2 (CONTINUED) Annual URCS Process for Region 7 - West 19-Dec-01

OUTPUT UNIT COSTS

UNIT COSTS FOR FREIGHT CAR OWNERSHIP AND MAINTENANCE

LINE	OPR EXPENSE UNIT COST CD(Y) RR OWNED (10)	DRL EXPENSE UNIT COST CD(Y) RR OWNED (11)	ROI EXPENSE UNIT COST CD(Y) RR OWNED (12)	DRL EXPENSE UNIT COST CM(R) PRIVATE LINE (13)
201	3.66386	50.14510	10.03440	0.20543
202	3.66386	50.14510	10.03440	0.20543
203	2.58752	12.12740	2.06242	0.00389
204	1.96312	8.31359	2.20731	0.00375
205	2.76424	7.94683	1.87014	0.00244
206	2.65224	9.38993	3.02453	0.07762
207	1.39649	2.25137	2.51716	0.00352
208	1.21673	8.16404	1.02842	0.00019
209	3.09884	6.01758	4.15146	0.00206
210	2.01735	7.10367	5.49391	0.06256
211	0.00000	0.00000	0.00000	0.19112
212	0.00000	0.00000	0.00000	0.14515
213	5.58324	16.94470	6.66582	0.15466
214	2.10585	13.40820	2.44880	0.22817
215	0.00000	0.00000	0.00000	0.06429
216	0.00000	0.00000	0.00000	0.06039
217	7.11993	1.86983	0.90426	0.01201
218	0.00000	0.00000	0.00000	0.02728
219	0.00005	0.04193	0.00656	0.00000
220	2.73849	9.37500	2.58918	0.08341
221	0.00000	0.00000	0.00000	0.14515

OUTPUT UNIT COSTS
UNIT COSTS FOR LOSS AND DAMAGE CLAIM PAYMENTS

LINE	STCC CODE	IDENTIFICATION	UNIT COST PER TON (1)
301	01	FARM PRODUCTS	0.04985
302	0113	GRAIN	0.02357
303	01195	POTATOES OTHER THAN SWEET	2.37051
304	012	FRESH FRUITS	0.21108
305	013	FRESH VEGETABLES	1.03734
306		ALL OTHER FARM PRODUCTS	0.03236
307	10	METALLIC ORES	0.02020
308	11	COAL	0.00287
309	14	NONMETALLIC MINERALS	0.00554
310	20	FOOD AND KINDRED PRODUCTS	0.15479
311	2011	FRESH MEATS	0.00046
312	202	DAIRY PRODUCTS	1.02544
313	203	CANNED FRUITS/VEG	0.63047
314	204	GRAIN MILL PRODUCTS	0.02277
315	2041	FLOUR	0.04470
316	2042	PREPARED FEEDS	0.00823
317	2043	CEREALS	2.23234
318	2044	RICE	0.18069
319	2045	PREPARED FLOUR	0.39921
320	2046	CORN PRODUCTS	0.01849
321	2062	REFINED SUGAR	0.09707
322	20821	BEER	0.40623
323	2084	WINES	0.36200
324	20851	WHISKEY	0.27697
325	209	MISC FOOD PREPARATIONS	0.06262
326		ALL OTHER FOOD PRODUCTS	0.28660
327	21	TOBACCO PRODUCTS	-0.20754
328	24	LUMBER AND WOOD EX FURNITURE	0.07642
329	2421	LUMBER/DIMENSION STOCK	0.11688
330	2432	PLYWOOD OR VENEER	0.15095
331		ALL OTHER LUMBER AND WOOD PRODUCTS	0.03813
332	25	FURNITURE AND FIXTURES	0.37086
333	26	PULP, PAPER AND ALLIED PRODUCTS	0.20303
334	26211	NEWSPRINT	0.20442
335	26213	PRINTING PAPER	0.51742
336	263	FIBREBD/PAPERDB/PULPDB	0.16174
337	264	COV PAPER/PAPERBOARD	0.21456
338	26471	SANITARY TISSUES	0.07676
339		ALL OTHER PULP, PAPER & ALLIED PRODUCTS	0.11470

WORKTABLE E1 PART 3 Annual URCS Process for Region 7 - West 19-Dec-01

OUTPUT UNIT COSTS

UNIT COSTS FOR LOSS AND DAMAGE CLAIM PAYMENTS

LINE	STCC CODE	IDENTIFICATION	UNIT COST PER TON (1)
340	28	CHEMICALS	0.05409
341	281	INDUSTRIAL CHEMICALS	0.01580
342	2812	POTASSIUM OR SODIUM	0.00963
343	282	SYN FIBRES/RESINS/RUBBER	0.12554
344	289	MISC CHEMICALS PRODUCTS	0.08544
345		ALL OTHER CHEMICALS	0.04839
346	29	PETROLEUM OR COAL PRODUCTS	0.01384
347	30	RUBBER AND MISC PLASTICS	0.53759
348	301	RUBBER TIRES/INNER TUBES	0.52007
349		ALL OTHER RUBBER PRODUCTS	0.55577
350	32	STONE, CLAY AND GLASS PRODUCTS	0.03508
351	321	FLAT GLASS	0.47774
352	3295	NONMETALLIC EARTH/MIN	0.02991
353		ALL OTHER STONE & CLAY, GLASS PRODUCTS	0.03764
354	33	PRIMARY METAL PRODUCTS	0.04239
355	3312	PRIMARY IRON/STEEL PRODUCTS	0.03198
356	3352	ALUMINUM BASIC SHAPES	0.78385
357		ALL OTHER PRIMARY METAL PRODUCTS	0.04557
358	34	FABRICATED METAL PRODUCTS	1.82016
359	344	FAB STRUC METAL PRODUCTS	0.92482
360		ALL OTHER FAB METAL PRODUCTS	2.34185
361	35	MACHINERY EXCEPT ELECTRICAL	0.42691
362	351	ENGINES/TURBINES	0.00000
363	352	FARM MACHINERY	1.40284
364	353	CONST MIN/MAT HAND MACHINERY	0.43753
365		ALL OTHER MACHINERY EXCEPT ELECTRICAL	0.27043
366	36	ELECTRICAL MACHINERY	1.18843
367	361	ELECTRICAL TRANS/DIST EQUIPMENT	9.47949
368	363	HOUSEHOLD APPLIANCES	0.30133
369	365	RADIO OR TV SETS	2.39744
370		ALL OTHER ELECTRICAL MACHINERY	0.13304
371	37	TRANSPORTAION EQUIPMENT	0.86243
372	37111	MOTOR PASSENGER CARS	1.15415
373	37112	MOTOR TRUCKS	1.02967
374	3714	MOTOR VECHICLE PARTS	0.25549
375		ALL OTHER TRANSPORTATION EQUIPMENT	0.18793
376	44	FREIGHT FORWARDER TRAFFIC	0.09412
377	45	SHIPPER ASSOCIATION TRAFFIC	0.17632
378	46	MISC MIXED SHIPMENTS	0.13858
379	461	MISC MIXED SHIPMENTS NEC INC TOFC	0.13840
380		ALL OTHER MIXED SHIPMENTS	0.14952
381	48	HAZARDOUS MATERIALS	0.02744
382	00	ALL OTHER COMMODITIES	0.10335

WORKTABLE E2 PART 1 Annual URCS Process for Region 7 - West 19-Dec-01

UNIT COST ADJUSTMENT FACTORS

FREIGHT CAR STATISTICS

LINE	EQUIPMENT	AVERAGE TARE WEIGHT (1)	CURRENT YR EMPTY/LOADED RATIO RR OWNED (2)	CURRENT YR EMPTY/LOADED RATIO PRIVATE LINE (3)
101	BOX - 40 FT	24.2	1.61635	1.24632
102	BOX - 50 FT	32.7	1.61635	1.24632
103	BOX - EQUIPPED	36.1	1.77201	1.77440
104	GONDOLA - PLAIN	27.3	2.01246	1.96291
105	GONDOLA - EQUIP.	33.1	1.89790	1.91388
106	HOPPER - COVERED	31.5	1.97448	1.80947
107	HOPPER - OTG	29.6	1.88629	1.96877
108	HOPPER - OTS	28.9	1.91957	1.98493
109	REFRIG - MECH	45.6	1.56753	1.87805
110	REFRIG - NM	43.1	1.64536	1.82536
111	FLAT - TOFC	58.6	1.11079	1.10049
112	FLAT - MULTILEVEL	54.2	1.49616	1.43314
113	FLAT - GENERAL	30.7	2.87247	1.61707
114	FLAT - OTHER	34.2	1.99523	1.71525
115	TANK <22,000 GAL	36.1	1.81356	1.75534
116	TANK >=22,000 GAL	36.1	1.81356	1.81253
117	ALL OTHER FC	36.1	1.81356	1.32139
118	AVERAGE FC	34.5	1.71218	1.57542

WORKTABLE E2 PART 1 (CONTINUED)

Annual URCS Process for Region 7 - West 19-Dec-01

LINE	CURRENT YR EMPTY/LOADED RATIO ALL CARS (4)	CIRCUITY LOCAL (5)	CIRCUITY INTERLINE (6)	CIRCUITY AVERAGE (7)	SPOTTED & PULLED RATIO (8)
101	1.37521	1.140	1.193	1.182	1.8
102	1.37521	1.122	1.187	1.176	1.8
103	1.77204	1.134	1.184	1.176	2.0
104	1.98025	1.093	1.151	1.134	2.0
105	1.89884	1.110	1.122	1.119	2.0
106	1.89168	1.126	1.164	1.148	2.0
107	1.89209	1.076	1.137	1.106	2.0
108	1.96331	1.202	1.156	1.183	2.0
109	1.57549	1.079	1.078	1.078	2.0
110	1.66260	1.118	1.159	1.153	2.0
111	1.10475	1.069	1.107	1.085	1.0
112	1.44031	1.061	1.166	1.152	2.0
113	2.61434	1.086	1.177	1.153	2.0
114	1.87033	1.088	1.170	1.155	2.0
115	1.75534	1.146	1.190	1.179	2.0
116	1.81253	1.146	1.190	1.179	2.0
117	1.73206	1.146	1.190	1.179	2.0
118	1.63870	1.097	1.157	1.135	1.9

WORKTABLE E2 PART 1 (CONTINUED)

Annual URCS Process for Region 7 - West 19-Dec-01

LINE	CD PER INDUSTRY SW (9)	CD PER INTERCH SW (10)	CD PER INTRATERM SW (11)	CD PER INTERTERM SW (12)	CD PER I & I SW (13)
101	1.0	0.5	2.0	1.5	0.5
102	1.0	0.5	2.0	1.5	0.5
103	1.0	0.5	2.0	1.5	0.5
104	1.0	0.5	2.0	1.5	0.5
105	1.0	0.5	2.0	1.5	0.5
106	1.0	0.5	2.0	1.5	0.5
107	1.0	0.5	2.0	1.5	0.5
108	1.0	0.5	2.0	1.5	0.5
109	1.0	0.5	2.0	1.5	0.5
110	1.0	0.5	2.0	1.5	0.5
111	1.0	0.5	2.0	1.5	0.5
112	1.0	0.5	2.0	1.5	0.5
113	1.0	0.5	2.0	1.5	0.5
114	1.0	0.5	2.0	1.5	0.5
115	1.0	0.5	2.0	1.5	0.5
116	1.0	0.5	2.0	1.5	0.5
117	1.0	0.5	2.0	1.5	0.5
118	1.0	0.5	2.0	1.5	0.5

LINE	CD PER L&UL INDUSTRY SW (14)	CD PER L&UL INTRATERM SW (15)	CD PER L&UL INTERTERM SW (16)	CM PER INDUSTRY SW (17)	CM PER INTERCH SW (18)
101	2.0	4.0	2.0	4.0	2.75
102	2.0	4.0	2.0	4.0	2.75
103	2.0	4.0	2.0	4.0	2.75
104	2.0	4.0	2.0	4.0	2.75
105	2.0	4.0	2.0	4.0	2.75
106	2.0	4.0	2.0	4.0	2.75
107	2.0	4.0	2.0	4.0	2.75
108	2.0	4.0	2.0	4.0	2.75
109	2.0	4.0	2.0	4.0	2.75
110	2.0	4.0	2.0	4.0	2.75
111	2.0	4.0	2.0	4.0	2.75
112	2.0	4.0	2.0	4.0	2.75
113	2.0	4.0	2.0	4.0	2.75
114	2.0	4.0	2.0	4.0	2.75
115	2.0	4.0	2.0	4.0	2.75
116	2.0	4.0	2.0	4.0	2.75
117	2.0	4.0	2.0	4.0	2.75
118	2.0	4.0	2.0	4.0	2.75

WORKTABLE E2 PART 1 (CONTINUED)

Annual URCS Process for Region 7 - West 19-Dec-01

LINE	CM PER INTRATERM SW (19)	CM PER INTERTERM SW (20)	CM PER I & I SW (21)	AVE CM(R) PER CD(R) (22)	AVE MILES BETWEEN I & I SW (23)	AVE MI B/ INTERCH EVENTS (24)
101	6.0	5.25	1.0	635.48	200.0	959.722
102	6.0	5.25	1.0	635.48	200.0	959.722
103	6.0	5.25	1.0	635.48	200.0	885.124
104	6.0	5.25	1.0	635.48	200.0	1206.680
105	6.0	5.25	1.0	635.48	200.0	786.709
106	6.0	5.25	1.0	635.48	200.0	1044.750
107	6.0	5.25	1.0	635.48	200.0	982.444
108	6.0	5.25	1.0	635.48	200.0	1392.320
109	6.0	5.25	1.0	635.48	200.0	1808.800
110	6.0	5.25	1.0	635.48	200.0	1252.650
111	6.0	5.25	1.0	635.48	200.0	4685.280
112	6.0	5.25	1.0	635.48	200.0	3080.390
113	6.0	5.25	1.0	635.48	200.0	445.102
114	6.0	5.25	1.0	635.48	200.0	1430.750
115	6.0	5.25	1.0	635.48	200.0	805.586
116	6.0	5.25	1.0	635.48	200.0	805.586
117	6.0	5.25	1.0	635.48	200.0	805.586
118	6.0	5.25	1.0	635.48	200.0	1246.770

LINE	CURRENT YR SEM PER INDUSTRY SW (25)	CURRENT YR SEM PER INTERCH SW (26)	CURRENT YR SEM PER INTRATER SW (27)	CURRENT YR SEM PER INTERTERM SW (28)	CURRENT YR SEM PER I & I SW (29)
101	6.41366	3.52751	9.62048	7.69639	1.60341
102	6.41366	3.52751	9.62048	7.69639	1.60341
103	6.41366	3.52751	9.62048	7.69639	1.60341
104	6.41366	3.52751	9.62048	7.69639	1.60341
105	6.41366	3.52751	9.62048	7.69639	1.60341
106	6.41366	3.52751	9.62048	7.69639	1.60341
107	6.41366	3.52751	9.62048	7.69639	1.60341
108	6.41366	3.52751	9.62048	7.69639	1.60341
109	6.41366	3.52751	9.62048	7.69639	1.60341
110	6.41366	3.52751	9.62048	7.69639	1.60341
111	6.41366	3.52751	9.62048	7.69639	1.60341
112	6.41366	3.52751	9.62048	7.69639	1.60341
113	6.41366	3.52751	9.62048	7.69639	1.60341
114	6.41366	3.52751	9.62048	7.69639	1.60341
115	6.41366	3.52751	9.62048	7.69639	1.60341
116	6.41366	3.52751	9.62048	7.69639	1.60341
117	6.41366	3.52751	9.62048	7.69639	1.60341

118	6.41366	3.52751	9.62048	7.69639	1.60341

WORKTABLE E2 PART 2 Annual URCS Process for Region 7 - West 19-Dec-01

UNIT COST ADJUSTMENT FACTORS

OTHER ADJUSTMENT FACTORS

LINE	CODE	IDENTIFICATION	AMOUNT (1)
201	AMCW	AVERAGE DISTANCE PER CAR IN WAY TRAINS	20.00980
202	A1802	AVERAGE TCU'S PER FLAT CAR	1.82864
203	A1805	AVERAGE TARE WEIGHT - REFRIG - TRAILER/CONTAINER	5.0
204	A1806	AVERAGE TARE WEIGHT - OTHER - TRAILER/CONTAINER	3.9
205	A1803	LINEHAUL MILES PER TRAILER DAY	478.0
206	A1804	TRAILER DAYS PER O OR T EVENT	3.645
207	A1801	L/E RATIO - REFRIG/OTHER - TRAILER/CONTAINER	1.48
208	ALUU	AVERAGE LOCO UNITS PER UNIT TRAIN	2.83833
209	ALUW	AVERAGE LOCO UNITS PER WAY TRAIN	2.24824
210	ALUT	AVERAGE LOCO UNITS PER THROUGH TRAIN	3.02769
211	AGTU	AVERAGE GROSS TONS - UNIT TRAIN	9148.9
212	AGTW	AVERAGE GROSS TONS - WAY TRAIN	2134.9
213	AGTT	AVERAGE GROSS TONS - THROUGH TRAIN	4985.3
214	402	ENGINE CREWS (EXCL TRAIN SWITCHING)	920082
215	403	TRAIN CREWS (EXCL. TRAIN SWITCHING)	797325
216		TOTAL CREW WAGES (EXCL. TRAIN SWITCHING)	1717410
217	TM(R)	TRAIN MILES - RUNNING	318992
218		AVERAGE CREW WAGES (ASSIGNED TO TRAIN MILES-CREW) PER TRAIN MILE	5.38385
219		GENERAL OVERHEAD RATIO	1.08661
220		CONSTANT COST MARKUP RATIO	1.35200

Appendix E. Detailed Track Working Papers

Table E.1. Detailed Track Maintenance Needs for the Davenport-to-Coulee City Line Segment

Milepost 43.00 to 108.46 = 65.46 miles

Description	**Total Number**	**Life Span Yrs**	**Replace Quantity**	**Units**	**Unit Cost**	**Total Cost**
Corrective main line rail	0	0	0	MI	200,000	$0
Main Line Rail						
115/0 RE CC CF&I 1950 JT(39)	1.72	85	0.020	MI	200,000	$4,047
112/28 RE OH Illinois 1944 CW(EL)	0.52	100	0.005	MI	200,000	$1,040
112/28 RE OH Illinois 1939 JT(39)	0.00	85	0.000	MI	200,000	$0
RE OH 100/25 Ill. 1926/31 JT(39)	11.08	50	0.2216	MI	200,000	$44,320
Colorado Sec 90/5, 1913/15 OH JT(33)	27.68	10	2.768	MI	200,000	$553,600
85/04 Ill. Steel Co. S. Wks. 1904/08 JT(33)	24.46	10	2.446	MI	200,000	$489,200
Total Rail Installed per Year	**65.46**		**5.461**			
Crossties (at 2,905/mile)	65.46	55	3,457	EA	40	$138,299
Corrective Surfacing		0	5	MI	12,000	$60,000
Surfacing	65.46	7	9.4	MI	12,000	$112,217
Corrective Ballast		0	20	CA	400	$8,000
Ballast (at 6 cars/mile)	65.46	7	56	CA	400	$22,443
M/L Turnouts Heavy Rail = 2	2	40	0.050	EA	40,000	$2,000
M/L Turnouts Small Rail = 27	27	10	2.700	EA	40,000	$108,000
Corrective Switch ties		0	168	EA	75	$12,600
Switch ties	29	25	1.16	SET	5,000	$5,800
Corrective Public Road Crossings = 6	214	0	32	TF	200	$6,400
Public Road Crossings = 52	1,720	20	86	TF	200	$17,200
Private Road Crossings = 28	448	10	44.8	TF	50	$2,240
Corrective Timber Bridge Repair	0	0	47	TF	100	$4,700
Timber Bridge Replacement = 15	731	50	14.62	TF	1,500	$21,930
Timber Deck Replacement	731	25	29.24	TF	100	$2,924
Corrective Ditching and Cribbing	0	0	5	WKS	5,000	$25,000
Ditching and Cribbing	65.46	30	2.18	WKS	5,000	$10,910
Corrective material: repair of broken joints @ 6/mi		70	346	EA	24	$8,304
Corrective material: anchor pattern @ 2000/mi		70	115,580	EA	0.40	$46,232
Tighten bolts and replace broken rail joints		70	57.79	MI	25,000	$1,444,750
Apply rail anchors		70	57.79	MI	10,000	$577,900
TOTAL						$3,730,057

Source: *Wilbur Smith Associates, 1999*

Table E.2. Detailed Track Maintenance Needs for the Cheney-to-Davenport Line Segment						
Milepost 1.00 to 43.00 = 42.00 miles						
Description	**Total Number**	**Life Span Yrs**	**Replace Quantity**	**Units**	**Unit Cost**	**Total Cost**
Main Line Rail						
115/25 RE CC BSCO Lackawanna 1949 JT(39)	1.4	85	0.016	MI	200,000	$3,294 ($3,200)
112/28 RE OH Illinois 1944 CW(EL)	4.00	100	0.040	MI	200,000	$8,000
112/28 RE OH Illinois 1939 JT(39)	1.60	85	0.019	MI	200,000	$3,765
RE OH 100/25 Ill. 1926/31 JT(39)	6.88	30	0.229	MI	200,000	$45,867
85/04 Ill. Steel Co. S. Wks. 1904/08 JT(33)	28.13	10	2.813	MI	200,000	$562,600
Total Rail Installed per Year	**42.01**		**3.117**			
Crossties (at 2,905/mile)	42.00	55	2,218	EA	40	$88,735
Corrective Surfacing		0	5	MI	12,000	$60,000
Surfacing	42.00	7	6.0	MI	12,000	$72,000
Corrective Ballast		0	20	CA	400	$8,000
Ballast (at 6 cars/mile)	42.00	7	36	CA	400	$14,400
Transportation of Ballast (on line)		0	0	CA	0	$0
M/L Turnouts not Used = 0	0	40	0	EA	0	$0
M/L Turnouts Heavy Rail = 11	11	40	0.275	EA	40,000	$11,000
M/L Turnouts Small Rail = 5	5	10	0.500	EA	40,000	$20,000
Corrective Switch ties		0	30	EA	75	$2,250
Switch ties	16	25	0.64	SET	5,000	$3,200
Corrective Public Road Crossings = 1	32	0	32	TF	200	$6,400
Public Road Crossings = 45	1,807	20	90.35	TF	200	$18,070
Private Road Crossings = 21	336	10	33.6	TF	50	$1,680
Corrective Timber Bridge Repair	47	0	47	TF	100	$4,700
Timber Bridge Replacement = 7	174	50	3.48	TF	1,500	$5,220
Timber Deck Replacement	174	25	6.96	TF	100	$696
Steel Bridge Replacement = 0	0	100	0	TF	3,000	$0
Steel Bridge Deck Replacement	0	25	0	TF	100	$0
Rail Top Culverts = 9	45	50	0.9	TF	1,500	$1,350
Corrective Ditching and Cribbing	0	0	5	WKS	5,000	$25,000
Ditching and Cribbing	42.00	30	1.40	WKS	5,000	$7,000
Corrective material- repair of broken rail joints @ 6/mi		70	152	EA	24	$3,648
Corrective material for standard anchor pattern @ 2000/mi		70	50,634	EA	0.40	$20,254
Tighten bolts and replace broken rail joints		70	25.32	MI	25,000	$633,000
Apply rail anchors		70	25.32	MI	10,000	$253,200
TOTAL						$1,883,328
Source: *Wilbur Smith Associates, 1999*						

Table E.3. Detailed Track Maintenance Needs for the Zangar Junction-to-Walla Walla Line Segment

Item	Description	Total Number	Life Span Yrs	Replace Quantity	Units	Unit Cost	Total Cost
1	Corrective main line rail	0	0	0	MI	200,000	$0
2	Main Line Rail						
	112/1 RE OH Colorado 1940/42 Jt(39) = 0.5 to 5.3	4.8	100	0.048	MI	200,000	$9,600
	Colorado Sec. 110 RE 1929/31 Jt(39) = 5.3 to 15.2	9.9	70	0.141	MI	200,000	$28,286
	133/0 RE CC CF&I 1949 Jt(39)						
	131/28 RE OH Ill. 1945 Jt(39) = 15.2 to 30.5	15.3	100	0.153	MI	200,000	$30,600
	Total Rail Installed per Year			**0.342**			
3	Corrective Crossties						
4	Crossties (at 3,100/mile)	30.00	55	1,691	EA	40	$67,636
5	Corrective Surfacing		0	5	MI	12,000	$60,000
6	Surfacing	30.00	7	4.3	MI	12,000	$51,429
7	Corrective Ballast		0	20	CA	400	$8,000
8	Ballast (at 6 cars/mile)	30.00	7	26	CA	400	$10,286
9	Transportation of Ballast (on line)		0	0	CA	0	$0
10	M/L Turnouts not Used = 3	3	40	0	EA	0	$0
11	M/L Turnouts = 5	5	40	0.125	EA	40,000	$5,000
12	Corrective Switch ties		0	49	EA	75	$3,675
13	Switch ties	5	25	0.2	SET	5,000	$1,000
14	Corrective Public Road Crossings						
15	Public Road Crossings = 28	891	20	44.55	TF	200	$8,910
16	Private Road Crossings = 24	384	10	38.4	TF	50	$1,920
17	Corrective Timber Bridge Repair	137	0	137	TF	100	$13,700
18	Timber Bridge Replacement = 8	498	50	9.96	TF	1,500	$14,940
19	Timber Deck Replacement	498	25	19.92	TF	100	$1,992
20	Steel Bridge Replacement = 4	358	100	3.58	TF	3,000	$10,740
21	Steel Bridge Deck Replacement	358	25	14.32	TF	100	$1,432
22	Corrective Ditching and Cribbing	0	0	5	WKS	5,000	$25,000
23	Ditching and Cribbing	30.00	30	1	WKS	5,000	$5,000
24	Corrective material for repair of broken rail joints		70	0	EA	24	$0
25	Corrective material for standard anchor pattern		70	0	EA	0.40	$0
26	Tighten bolts and replace broken rail joints		70	0	MI	25,000	$0
27	Apply rail anchors		70	0	MI	10,000	$0
	TOTAL						**$359,145**

Source: *Wilbur Smith Associates, 1999*

Table E.4. Detailed Track Maintenance Needs for the Walla Walla-to-Dayton Branch							
Item	**Description**	**Total Number**	**Life Span Yrs**	**Replace Quantity**	**Units**	**Unit Cost**	**Total Cost**
1	Corrective main line rail	0	0	0	MI	200,000	$0
2	Main Line Rail						
	Mixed rail 75/80/90/100 = 30.5 to 47.25	0.75	30	0.025	MI	200,000	$5,000
	75/10 Ill. Steel Wks. 1898 JT (30) = 47.25 to 58.3	11.05	5	2.210	MI	200,000	$442,000
	80/04 Ill. Steel C.S. Wks. 1900 JT (30) = 58.3 to 70.1	11.80	7	1.686	MI	200,000	$337,143
	85 lb. JT = 70.1 to 71.3	1.20	10	0.12	MI	200,000	$24,000
	75/10 Ill. Steel Wks. 1899JT(30) = 0.0 to 5.3	5.30	5	1.060	MI	200,000	$212,000
	85/04 Ill. Steel Co. S. Wks. 1907 JT (33) = 5.3 to 13.1	7.80	10	0.78	MI	200,000	$156,000
	Total Rail Installed per Year						1,176,143
3	Corrective Crossties						
4	Crossties (at 3,100/mile)	37.90	55	2,136	EA	40	$85,447
5	Corrective Surfacing		0	5	MI	12,000	$60,000
6	Surfacing	37.90	7	5.4	MI	12,000	$64,971
7	Corrective Ballast		0	20	CA	400	$8,000
8	Ballast (at 6 cars/mile)	37.90	7	32	CA	400	$12,994
9	Transportation of Ballast (on line)		0	0	CA	0	$0
10	M/L Turnouts not Used = 14	14	40	0	EA	0	$0
11	M/L Turnouts, All Small Rail = 19	19	10	1.900	EA	40,000	$76,000
12	Corrective Switch ties		0	207	EA	75	$15,525
13	Switch ties	19	25	0.76	SET	5,000	$3,800
14	Corrective Public Road Crossings = 4	150	0	150	TF	200	$30,000
15	Public Road Crossings = 40	1,476	20	73.8	TF	200	$14,760
16	Private Road Crossings = 56	968	10	96.8	TF	50	$4,840
17	Corrective Timber Bridge Repair	106	0	106	TF	100	$10,600
18	Timber Bridge Replacement = 17	689	50	13.78	TF	1,500	$20,670
19	Timber Deck Replacement	689	25	27.56	TF	100	$2,756
20	Steel Bridge Replacement = 9	1,036	100	10.36	TF	3,000	$31,080
21	Steel Bridge Deck Replacement	1,036	25	41.44	TF	100	$4,144
22	Corrective Ditching and Cribbing	0	0	5	WKS	5,000	$25,000
23	Ditching and Cribbing	37.90	30	1.26	WKS	5,000	$6,317
24	Corrective material for repair of broken rail joints @ 24/mi		70	768	EA	24	$18,432
25	Corrective material for standard anchor pattern @ 4000/mi		70	128,080	EA	0.40	$51,232
26	Tighten bolts and replace broken rail joints		70	32.02	MI	25,000	$800,500
27	Apply rail anchors		70	32.02	MI	10,000	$320,200
	TOTAL						**$2,843,412**

Source: *Wilbur Smith Associates, 1999*

Appendix F. Equated Track Maintenance Factors

Table F.1. Equated Track Maintenance Factors for Track Types and Components

Track Type	Description	Factors by Speed Classification Freight/Passenger				
		1	**2**	**3**	**4**	**5**
		10/15	**25/30**	**40/60**	**60/80**	**80/90**
Main Tracks	1st	0.55	0.69	0.87	1.00	1.13
	2nd	0.45	0.58	0.78	0.89	1.01
	3rd and 4th	0.37	0.52	0.67	0.77	0.95
Branch-line Tracks	–	0.50	0.52	0.72	0.90	
Other Tracks	Passing and Thoroughfare	0.32	0.43	0.50	0.80	
	CTC Passing	0.40	0.63	0.83	0.95	
	Yard and Side	0.39	0.50			
Turnouts	Main Track (each)	0.04	0.05	0.12	0.12	0.15
	Side Track (each)	0.03	0.08	0.09		
	Power or Spring (each)	0.06	0.07	0.17	0.19	
Railway Crossings	Each	0.10	0.15	0.18	0.20	0.24
Road Crossings	Paved Street or Highway (Ea/Tr)	0.09	0.09	0.09	0.10	0.10
	Unpaved Street or Highway (Ea/Tr)	0.04	0.05	0.05	0.06	0.06
	Unimproved Road (Ea/Tr)	0.02	0.02	0.03	0.03	0.03
	Farm or Private (Ea/Tr)	0.02	0.02	0.02	0.02	0.02

Source: *Manual for Railway Engineering (AREMA, 2000), Table 11-1*

Table F.2 Adjustments to Equated Track Maintenance Factors for Track Component, Track Geometry, and Traffic Loading Factors						
Track Component	**Description**	**Factors by Speed Classification Freight/Passenger**				
		1	**2**	**3**	**4**	**5**
		10/15	**25/30**	**40/60**	**60/80**	**80/90**
Ballast	Crushed Rock	0.90	0.93	0.96	0.98	1.00
	CR Washed and Screened	0.95	0.96	1.00	1.20	
	CR Pit Run Gravel	1.04	1.04	1.12		
	Pit Run Gravel	1.06	1.11	1.22		
Rail Weight	Under 110 lb/yd	1.08	1.09	1.16	1.43	
	110-116 lb/yd	1.05	1.05	1.05	1.20	
	116-132 lb/yd	1.00	1.00	1.01	1.02	1.02
	Over 132 lb/yd	0.83	0.90	0.92	0.95	0.97
CWR		0.59	0.70	0.76	0.80	0.82
Curves	Degrees 0-2	1.03	1.03	1.04	1.05	1.06
	2-4	1.20	1.22	1.25	1.30	
	4-6	1.40	1.42	1.50		
	Over 6	2.00	2.02	2.23		
Axle Loads	45,000 lb	0.95	0.95	0.95	0.96	0.97
	55,000 lb	1.02	1.02	1.02	1.06	1.09
	66,000 lb	1.24	1.30	1.30	1.40	1.45
	Over 66,000 lb	1.50	1.50	1.50	1.70	2.07
Unit Trains– Each Direction	1-5 Per Day	1.02	1.02	1.02	1.06	1.09
	Over 5 Per Day	1.09	1.09	1.13	1.18	1.29
Source: *Manual for Railway Engineering (AREMA, 2000), Table 11-2*						

Table F.3 Traffic Density Factors for Adjusting Equated Track Maintenance Factors						
Traffic Loading	**Description**	**Factors by Speed Classification Freight/Passenger**				
		1	**2**	**3**	**4**	**5**
		10/15	**25/30**	**40/60**	**60/80**	**80/90**
Million Gross Tons Per Year	0-5	0.39	0.50	0.56	0.70	0.75
	5-10	0.44	0.56	0.64	0.74	0.83
	10-15	0.51	0.62	0.73	0.84	0.93
	15-20	0.56	0.67	0.81	0.90	1.03
	20-25	0.63	0.75	0.89	1.00	1.14
	25-30	0.73	0.81	0.95	1.07	1.23
	30-35	0.74	0.89	1.00	1.12	1.32
	Over 35	0.82	0.93	1.05	1.22	1.41
Source: *Manual for Railway Engineering (AREMA, 2000)*						

Appendix G. Estimated Net Liquidation Values for PCC Line Segments

The estimated track net liquidation values used in this study are provided by Wilbur Smith Associates. These estimates are based on detailed field surveys conducted in 1998 and 1999.

The quantities and descriptions of track materials have not changed appreciably since the field survey was conducted. The prices of materials may vary from year-to-year and fluctuate based on market demand and scarcity of materials. However, if the unit prices used in this analysis have increased materially during the last three years, then the removal costs may have increased as well. Thus, the effects of potential price increases on net liquidation values may be dampened by potential increases in removal costs.

Cheney-to-Coulee City Line

Cheney-to-Davenport Segment

Table G.1 shows the estimated track salvage value of assets in the Cheney-to-Davenport segment of the line ($1,475,480). Table G.2 shows the estimated removal cost of these assets ($565,928). The estimated net liquidation value (NLV) of this segment is$909,552.

Table G.1 Estimated Track Salvage Value of the Cheney-to-Coulee City Rail Line

Cheney-to-Davenport Segment: MP 0.00 to 43.00

Quantity	Unit	Net Tons	Description of Item	Unit Price	Total Cost
22,842	EA	0.0	Cross Ties - Reuseable	$5.00	$114,210
			Timbered In 1988 @ 401 Ties/Mi		
6,300	EA	0.0	Cross Ties - Reuseable	$20.00	$126,000
			Timbered In 1998		
67,668	EA	0.0	Cross Ties - Landscape	$1.60	$108,269
14,784	LF	283.4	115# JT Rail - Relay(CL#1)	$425.00	$120,449
			115/25 RE CC Illinois 1947 JT		
			115 RE CC BSCO Lackawanna 1949 JT(39)		
13,200	LF	234.0	112# CW Rail - Relay(CL#1)	$450.00	$105,316
			112 RE OH BSCO Lackawanna 1940/43 CW		
			112/28 RE OH Illinois 1944 CW(EL)		
23,126	LF	410.0	112# CW Rail - Relay(CL#2)	$300.00	$123,007
			112/28 RE OH Illinois 1944 CW(EL)		
			112/1 RE Colorado 1945 CE(EL)		

Table G.1 Estimated Track Salvage Value of the Cheney-to-Coulee City Rail Line					
Cheney-to-Davenport Segment: MP 0.00 to 43.00					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
2,112	LF	37.4	112# CW Rail - Relay(CL#3)	$175.00	$6,553
3,696	LF	65.5	112# CW Rail - Scrap	$90.00	$5,898
16,896	LF	299.6	112# JT Rail - Relay(CL#2)	$250.00	$74,892
			112/28 RE OH Illinois 1939 JT(39)		
			112/1 RE OH Colorado 1943 JT(39)		
72,652	LF	1,150.8	100# JT Rail - Scrap	$90.00	$103,573
			RE OH 100/25 Illinois 1926/31 JT(39)		
			100 RE BSCO Lackawanna OH 1925/28		
			100-Area JT(39)		
297,052	LF	3,998.3	85# JT Rail - Scrap	$90.00	$359,849
			85/04 ILL Steel CO. S. WKS 1904/08 JT(33)		
			L.S. CO Buffalo 85/0 1906/08 JT(33)		
2	EA	7.9	#11, 112# RBM MAG, 19-6 PTS	$4,000.00	$8,000
3	EA	10.9	#9, 115# RBM, 16-6 PTS	$4,000.00	$12,000
6	EA	24.4	#11, 115# RBM, 19-6 PTS	$4,000.00	$24,000
6	EA	14.8	#9, 85# Turnouts - Scrap	$295.00	$1,770
79	PR	2.9	115# 24" - 4 Hole JT. Bars - Scrap	$2.95	$233
			Drill = 6 12/ - 5 - 6 1/2		
150	PR	8.0	115# 39" - 6 Hole Angle. Bars - Scrap	$4.25	$638
			Drill = 6-6-7		
150	PR	7.4	115# 36" - 6 Hole JT. Bars - Scrap	$3.95	$593
			Drill = 6-6-7		
33	PR	1.7	112# 39" - 6 Hole Angle. Bars - Scrap	$4.15	$137
400	PR	14.3	112# 24" - 4 Hole JT. Bars - Scrap	$2.85	$1,140
			Drill = 6-5-6 And 6 1/2- 5 - 6 1/2		
1,862	PR	59.6	100# 24" 4-Hole Angle Bars - Scrap	$2.55	$4,748
			Drill = 5 1/2 All & 6-5-6		
9,002	PR	243.1	85# 24" 4-Hole Angle Bars - Scrap	$2.15	$19,354
			Drill = 6" All		
6,000	EA	60.0	Tieplates, 7 3/4 X 13 & 14" DS 8 Hole - Relay	$2.55	$15,300
34,612	EA	250.9	Tieplates, 7 3/4 X 11" D.S. 4&6 Hole - Relay	$1.15	$39,804
			With Mixed 8 1/2 X 12" D.S. 8-H		
65,394	EA	408.7	Tieplates, 7 1/2 X 10 1/2" S.S. 6H - Scrap	$0.50	$32,697
			& 7 3/4 X 11"ON 85 & 100# Rail		
117,673	EA	353.0	Tieplates, 6 X 8 1/2" 2H/4H S.S. - Scrap	$0.25	$29,418
41,940	EA	41.9	Rail Anchors, Mixed - Relay	$0.35	$14,679
86,912	EA	86.9	Rail Anchors, Mixed - Scrap	$0.08	$6,953
1	LS	200.0	MISC. O.T.M.	$80.00	$16,002
Track Salvage Value for Cheney-to-Davenport Segment					**$1,475,480** **($1,475,482)**
Source: *Wilbur Smith Associates, 1999*					

Table G.2. Estimated Removal Cost of Track Assets in the Cheney-to-Coulee City Rail Line				
Cheney-to-Davenport Segment: MP 1.00 to 43.00				
Quantity	**Unit**	**Description of Item**	**Unit Price**	**Total Cost**
21,067	TF	Welded Rail Removal	$2.10	$44,241
221,760	TF	Jointed Rail Removal	$1.65	$365,904
1,807	TF	Restore 45 Paved Public Road X-ings	$55.00	$99,385
336	TF	Restore 21 Unpaved Priv. Road X-ings	$10.00	$3,360
158	TF	Remove 6 Ea Timb. Pile & Frame Trestles	$11.00	$1,738
45	TF	Remove 9 Ea Rail Top Box Culverts	$20.00	$900
25,200	EA	Dispose of Scrap Ties	$2.00	$50,400
Removal Cost of Track Assets in the Cheney-to-Davenport Segment				**$565,928**
Source: *Wilbur Smith Associates, 1999*				

Davenport-to-Coulee City Segment

Table G.3 shows the estimated track salvage value of assets in the Davenport-to-Coulee City segment of the line ($1,642,990). Table G.4 shows the estimated removal cost of these assets ($758,432). The estimated net liquidation value (NLV) of this segment is$884,558. The NLV for the entire Cheney-to-Coulee City Line is $1,794,110.

Table G.3. Estimated Track Salvage Value of the Cheney-to-Coulee City Rail Line					
Davenport-to-Coulee City Segment: MP 43.00 to 108.46					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
20,880	EA	0.0	Cross Ties - Reuseable	$5.00	$104,400
			Timbered In 1988/93 @ 181/477 Ties/Mi		
3,500	EA	0.0	Cross Ties - Reuseable	$20.00	$70,000
			Timbered In 1998		
126,505	EA	0.0	Cross Ties - Landscape	$1.60	$202,408
2,323	LF	44.5	115# JT Rail – Relay (CL#1)	$425.00	$18,926
			115/0 RE CC CF & I 1950 JT(39)		
15,840	LF	288.4	115# JT Rail - Relay(CL#2)	$250.00	$72,112
			115/0 RE CC CF & I 1950 JT(39)		
5,492	LF	97.4	112# CW Rail - Relay(CL#2)	$300.00	$29,212
			112/28 RE OH Illinois 1944 CW(EL)		
28,406	LF	450.0	100# JT Rail - Scrap	$90.00	$40,496
			RE OH 100/25 Illinois 1926/31 JT(39)		
			100 RE BSCO Lackawanna OH 1925/28		
			100-Area JT(39)		
88,598	LF	1,403.4	100# JT Rail - Scrap	$90.00	$126,305
			OH CF & I CO. SEC 100/2, 1912 JT		
			OH 100 LB, 161 PS CO. 1912 JT		
292,300	LF	4,165.3	90# JT Rail - Scrap	$90.00	$374,875
			ARA-B OH 90/30 Illinois 1919/20 JT		

Table G.3. Estimated Track Salvage Value of the Cheney-to-Coulee City Rail Line					
Davenport-to-Coulee City Segment: MP 43.00 to 108.46					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
			Colorado SEC 90/5, 1913/15 OH JT(33)		
			Lackawanna 90/32 RA-B, 1901/17 JT		
			90/30 Illinois Steel CO. S. WKS. 1901 JT		
			L.S. CO. Buffalo 90/32, 1901 JT		
258,298	LF	3,476.7	85# JT Rail - Scrap	$90.00	$312,902
			85/04 ILL Steel CO. S. WKS 1904/08 JT(33)		
			L.S. CO Buffalo 85/0 1906/08 JT(33)		
1	EA	3.6	#9, 115# RBM, 16-6 PTS	$4,000.00	$4,000
2	EA	7.3	#9, 115# RBM, 16-6 PTS New W/Pandrol	$20,000.00	$40,000
1	EA	4.1	#11, 115# RBM, 19-6 PTS	$4,000.00	$4,000
2	EA	5.8	#9, 100# Turnouts - Scrap	$345.00	$690
24	EA	62.3	#9, 90# Turnouts - Scrap	$310.00	$7,440
4	EA	9.9	#9, 85# Turnouts - Scrap	$295.00	$1,180
465	PR	23.0	115# 36" - 6 Hole JT. Bars - Scrap	$3.95	$1,837
			Drill = 6-6-7		
2,684	PR	96.1	100# 24" - 4 Hole JT. Bars - Scrap	$2.55	$6,844
			Drill = 6-5-6		
728	PR	23.3	100# 24" 4-Hole Angle Bars - Scrap	$2.55	$1,856
			Drill = 5 1/2 All & 6-5-6		
8,857	PR	265.7	90# 24" 4-Hole Angle Bars - Scrap	$2.40	$21,257
			Drill = 6 - 5 - 6		
7,827	PR	211.3	85# 24" 4-Hole Angle Bars - Scrap	$2.15	$16,828
			Drill = 6" All		
9,993	EA	99.9	Tieplates, 8 1/2 X 13 & 14" DS 8 Hole - Relay	$2.55	$25,482
3,021	EA	21.9	Tieplates, 7 3/4 X 11" D.S. 4&6 Hole - Relay	$1.15	$3,474
			With Mixed 8 1/2 X 12" D.S. 8-H		
112,465	EA	702.9	Tieplates, 7 1/2 X 10 1/2" S.S. 6H - Scrap	$0.50	$56,233
			& 7 3/4 X 11"ON 85 & 100# Rail		
218,112	EA	654.3	Tieplates, 6 X 8 1/2" 2H/4H S.S. - Scrap	$0.25	$54,528
13,400	EA	13.4	Rail Anchors, Mixed - Relay	$0.35	$4,690
200,960	EA	201.0	Rail Anchors, Mixed - Scrap	$0.08	$16,077
1	LS	311.7	MISC. O.T.M.	$80.00	$24,939
Track Salvage Value of Davenport-to-Coulee City Segment					**$1,642,990**
Source: *Wilbur Smith Associates, 1999*					

Table G.4. Estimated Removal Cost of Track Assets in the Cheney-to-Coulee City Rail Line				
Davenport-to-Coulee City Segment: MP 43.00 to 108.46				
Quantity	**Unit**	**Description of Item**	**Unit Price**	**Total Cost**
5,492	TF	Welded Rail Removal	$2.10	$11,533
340,137	TF	Jointed Rail Removal	$1.65	$561,226
1,720	TF	Restore 52 Paved Public Road X-ings	$55.00	$94,600
448	TF	Restore 28 Unpaved Priv. Road X-ings	$10.00	$4,480
731	TF	Remove 15 Ea Timb. Pile & Frame Trestles	$11.00	$8,041
39,276	EA	Dispose Of Scrap Ties	$2.00	$78,552
Removal Cost of Track Assets in the Davenport-to-Coulee City Segment				**$758,432**
Source: *Wilbur Smith Associates, 1999*				

Marshall-to-Moscow Line

Table G.5 shows the estimated track salvage value of assets in the Marshall-to-Moscow Line ($4,967,473). Table G.6 shows the estimated removal cost of these assets ($1,322,961). The estimated net liquidation value of this line is $3,644,512. Approximately $225,000 of this NLV is attributable to the Pullman-to-Moscow segment. When this segment is excluded, the estimated NLV drops to $3,419,500.

Table G.5. Estimated Track Salvage Value of the Marshall-to-Moscow Rail Line					
Milepost 1.00 to 84.05 (State Line)					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
22,361	EA	0.0	Cross Ties - Reuseable	$5.00	$111,805
			Timbered In 1973 & 1974 @ 312 To 432/Mi		
12,129	EA	0.0	Cross Ties - Reuseable	$8.00	$97,032
			Timbered In 1992 & 1994 @ 333 To 634/Mi		
186,626	EA	0.0	Cross Ties - Landscape	$1.60	$298,602
211	LF	3.3	132# JT Rail - Relay(CL#2)	$275.00	$919
			In Former Railroad Dia.		
12,038	LF	190.7	115# CW Rail - Relay(CL#2)	$325.00	$61,972
7,181	LF	113.7	115# CW Rail - Relay(CL#1)	$410.00	$46,636
			115RE CC Beth Steelton 1944 CW(EL)		
14,995	LF	237.5	115# JT Rail - Relay(CL#2)	$275.00	$65,318
			115/25 E CC Inland 1956 JT(39)		
363,475	LF	5,757.4	112# CW Rail - Relay(CL#2)	$325.00	$1,871,169
			112/28 RE OH ILL & IND 1941-45 CW(EL)		
			112RE OH BSCO Lackawanna 1938-45 CW(EL)		
			112/1 RE OH Colorado 1941-45 CW(EL)		
123,341	LF	1,953.7	112# JT Rail - Relay(CL#2)	$275.00	$537,273
			112RE BSCO Lackawanna 1942 JT(39)		
			112/1 RE OH Colorado 1943 JT(39)		

Table G.5. Estimated Track Salvage Value of the Marshall-to-Moscow Rail Line					
Milepost 1.00 to 84.05 (State Line)					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
			112/28 RE OH Inland 1944 JT(72)		
32,525	LF	515.2	112# JT Rail - Relay(CL#3)	$210.00	$108,191
			112/1 RE OH Colorado 1941 JT(39)		
			112/28 RE OH ILL 1939-43 JT(39)		
146,890	LF	2,326.7	100# JT Rail - Scrap	$120.00	$279,209
			RE OH 100/25 ILL 1928 JT(39)		
			BSCO Lackawanna OH 1929, 100AREA JT(39)		
207,610	LF	3,288.5	90# JT Rail - Scrap	$120.00	$394,625
			ARA-B OH 90/30 ILL 1919 JT(33)		
			Lackawanna 90/32, 1912 JT(33)		
			L.S. CO. Buffalo 90/32 1909 JT(33)		
73,286	LF	1,160.9	85# JT Rail - Scrap	$120.00	$139,302
			85/04 ILL Steel 1903-06 JT(28-31)		
			L.S. CO Buffalo 85/0 1908 JT(33)		
9,504	LF	112.8	75# JT Rail - Scrap	$120.00	$13,537
3,273	LF	33.7	66# JT Rail - Scrap	$120.00	$4,049
3	EA	11.8	#11, 112# Solid MAG, 19-6 PTS	$4,000.00	$12,000
11	EA	38.9	#9, 112# Solid MAG, 16-6 PTS	$4,000.00	$44,000
1	EA	3.6	#9, 115# RBM, 16-6 PTS	$4,000.00	$4,000
1	EA	3.6	#9, 115# RBM, 16-6 PTS New W/Pandrol	$20,000.00	$20,000
3	EA	12.2	#11, 115# RBM, 19-6 PTS	$4,000.00	$12,000
2	EA	8.1	#11, 115# RBM, 19-6 PTS New W/Pandrol	$25,000.00	$50,000
9	EA	26.0	#9, 100# Turnouts - Scrap	$345.00	$3,105
27	EA	70.1	#9, 90# Turnouts - Scrap	$310.00	$8,370
2	EA	5.5	#11, 90# Turnouts - Scrap	$325.00	$650
5	EA	12.4	#9, 85# Turnouts - Scrap	$295.00	$1,475
1	EA	1.9	#9, 66# Turnout - Scrap	$225.00	$225
4	PR	0.2	132# 36" - 6 Hole JT. Bars - Scrap	$6.30	$25
384	PR	19.0	115# 36" - 6 Hole JT. Bars - Scrap	$5.45	$2,093
			Drill = 6-6-7		
3,996	PR	143.1	112# 24" - 4 Hole JT. Bars - Scrap	$3.95	$15,784
			Drill = 6-5-6 And 6 1/2- 5 - 6 1/2		
3,766	PR	120.5	100# 24" 4-Hole Angle Bars - Scrap	$3.50	$13,181
			Drill = 5 1/2 All		
6,291	PR	188.7	90# 24" 4-Hole Angle Bars - Scrap	$3.30	$20,760
			Drill = 6 - 5 - 6		
2,364	PR	66.2	85# 24" 4-Hole Angle Bars - Scrap	$3.10	$7,328
			Drill = 6" All		
412	PR	10.3	56-75# 24" 4-Hole Angle Bars - Scrap	$2.75	$1,133
304,089	EA	2,128.6	Tieplates, 7 3/4 X 11" D.S. 4&6 Hole - Relay	$1.55	$471,338
			With Mixed 8 1/2 X 12" D.S. 8-H		
163,929	EA	901.6	Tieplates, 7 1/2 X 11" S.S. - Scrap	$0.60	$98,357
			On All 90 & 100# Rail		

Table G.5. Estimated Track Salvage Value of the Marshall-to-Moscow Rail Line					
Milepost 1.00 to 84.05 (State Line)					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
34,823	EA	121.9	Tieplates, 6 X 9 & 7 X 9" S.S. - Scrap	$0.35	$12,188
221,209	EA	221.2	Rail Anchors, Mixed - Relay	$0.35	$77,423
101,110	EA	101.1	Rail Anchors, Mixed - Scrap	$0.11	$11,122
1	LS	466.1	MISC. O.T.M.	$110.00	$51,274
Track Salvage Value of the Marshall-Moscow Line					**$4,967,473**
Source: *Wilbur Smith Associates, 1998*					

Table G.6 Estimated Removal Cost of Track Assets in Marshall-to-Moscow Line				
Quantity	**Unit**	**Description of Item**	**Unit Price**	**Total Cost**
191,347	TF	Welded Rail Removal	$2.10	$401,829
305,817	TF	Jointed Rail Removal	$1.65	$504,598
3,094	TF	Restore 67 Paved Public Road X-ings	$55.00	$170,170
1,360	TF	Restore 69 Unpaved Priv. Road X-ings	$10.00	$13,600
3,517	TF	Remove 68 Ea Timber Pile Trestles	$11.00	$38,687
147	TF	Remove 4 Ea Timber Frame Trestles	$11.00	$1,617
57	TF	Remove 9 Ea Rail Top Box Culverts	$20.00	$1,140
560	TF	Remove 6 Ea Steel (DPG, TPG, ETC)	$115.00	$64,400
63,460	EA	Dispose Of Scrap Ties	$2.00	$126,920
Removal Cost of Track Assets in the Marshall-Moscow Line				**$1,322,961**
Source: *Wilbur Smith Associates, 1998*				

Hooper Junction-to-Pullman Segment

Hooper Junction to Winona

Table G.7 shows the estimated track salvage value of assets in the Hooper Junction-to-Winona segment of the line ($1,464,653). Table G.8 shows the estimated removal cost of these assets ($330,514). The estimated net liquidation value of this segment is $1,134,139.

Table G.7. Estimated Track Salvage Value of Hooper Junction-to-Pullman Line					
Hooper Junction-to-Winona Segment: MP 25.25 to 52.00					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
32,382	EA	0.0	Cross Ties - Reuseable	$5.00	$161,910
30,349	EA	0.0	Cross Ties - Landscape	$1.60	$48,558
69,696	LF	1,545.2	133# JT Rail - Relay(CL#1)	$450.00	$695,322
			133/0 RE CC CF&I 1948/57 JT(39)		
			133/31 RE CC USS ILL. 1953/54 JT(39)		
6,441	LF	135.6	133# JT Rail - Relay(CL#2)	$250.00	$33,912
			133/0 RE CC CF&I 1948/57 JT(39)		
			133/31 RE CC USS ILL. 1953/54 JT(39)		
73,392	LF	1,162.5	100# JT Rail - Scrap	$90.00	$104,628

Table G.7. Estimated Track Salvage Value of Hooper Junction-to-Pullman Line					
Hooper Junction-to-Winona Segment: MP 25.25 to 52.00					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
			RE OH 100/25 ILL 1917/20 JT(33)		
130,838	LF	2,072.5	90# JT Rail - Scrap	$90.00	$186,523
			Colorado SEC 90ARA, 1915/23 OH JT(33)		
			OH CF & I CO 90 ARA, 1910 JT		
			ARA 90/20 ILL Steel S. WKS. 1909/12 JT(33)		
13,200	LF	156.7	75# JT Rail - Scrap	$90.00	$14,102
4	EA	17.4	#10, 133# SPG & Bolted Turnouts-Relay	$5,000.00	$20,000
10	EA	26.0	#10, 90# Turnouts - Scrap	$205.00	$2,050
4	EA	8.7	#9, 75# Turnouts - Scrap	$170.00	$680
1,952	PR	112.2	133# 38" - 6 Hole JT. Bars - Scrap	$4.60	$8,979
			Drill = 6 - 6 - 7		
2,224	PR	71.2	100# 27" 4-Hole Angle Bars - Scrap	$2.55	$5,671
			Drill = 5 1/2 All		
3,964	PR	118.9	90# 27" 4-Hole Angle Bars - Scrap	$2.40	$9,514
			Drill = 5 1/2 All		
400	PR	11.2	75# 24" 4-Hole Angle Bars - Scrap	$2.20	$880
41,990	EA	450.8	Tieplates, 7 3/4 X 14" D.S. 6 Hole - Relay	$2.35	$98,677
6,000	EA	48.0	Tieplates, 7 3/4 X 12" D.S. 9 Hole Com-Relay	$2.00	$12,000
			On 90 & 100# Rail		
101,924	EA	509.6	Tieplates, 7 3/4 X 9" S.S. - Scrap	$0.40	$40,770
17,568	EA	17.6	Rail Anchors, Mixed - Relay	$0.35	$6,149
46,410	EA	46.4	Rail Anchors, Mixed - Scrap	$0.08	$3,713
1	LS	132.7	MISC. O.T.M.	$80.00	$10,617
Track Salvage Value of the Hooper Junction-Winona Segment					**$1,464,653**
Source: *Wilbur Smith Associates, 1999*					

Table G.8 Estimated Track Removal Cost of Hooper Junction-to -Pullman Line				
Hooper Junction-to-Winona Segment: MP 25.25 to 52.00				
Quantity	**Unit**	**Description of Item**	**Unit Price**	**Total Cost**
0	TF	Welded Rail Removal	$2.10	$-
141,240	TF	Jointed Rail Removal	$1.65	$233,046
230	TF	Restore 7 Paved Public Road X-Ings	$55.00	$12,650
240	TF	Restore 15 Unpaved Priv. Road X-Ings	$10.00	$2,400
1,022	TF	Remove 11 Ea Timb Pile & Frame Trestles	$11.00	$11,242
302	TF	Remove 1 Ea Steel (DPG, TPG, ETC)	$115.00	$34,730
18,223	EA	Dispose Of Scrap Ties	$2.00	$36,446
Removal Cost of Track Assets in the Hooper Junction-to-Winona Segment				**$330,514**
Source: *Wilbur Smith Associates, 1999*				

Winona to Colfax

Table G.9 shows the estimated track salvage value of assets in the Winona-to-Colfax segment of the line ($1,188,610). Table G.10 shows the estimated removal cost of these assets ($364,281). The estimated net liquidation value of this segment is $824,329.

Table G.9. Estimated Track Salvage Value of Hooper Junction-to-Pullman Line

Winona-to-Colfax Segment: MP 52.00 To 78.10

Quantity	Unit	Net Tons	Description of Item	Unit Price	Total Cost
30,400	EA	0.0	Cross Ties - Reuseable	$5.00	$152,000
26,615	EA	0.0	Cross Ties - Landscape	$1.60	$42,584
4,224	LF	93.6	133# JT Rail - Relay(CL#1)	$450.00	$42,141
			133/0 RE CC CF&I 1948/57 JT(39)		
			133/31 RE CC USS ILL. 1953/54 JT(39)		
44,352	LF	968.2	131# JT Rail - Relay(CL#1)	$450.00	$435,692
			131/1 RE OH Colorado 1941/44 JT(39)		
			131/28 RE OH Inland 1941 JT		
137,491	LF	2,177.9	100# JT Rail - Scrap	$90.00	$196,007
			RE OH 100/25 ILL 1918/21 JT(33)		
			Colorado SEC 100/25 1917/30 OH JT		
89,549	LF	1,418.5	90# JT Rail - Scrap	$90.00	$127,661
			Colorado SEC 90ARA, 1915/23 OH JT(33)		
			OH CF & I CO 90 ARA, 1910 JT		
			ARA 90/20 ILL Steel S. WKS. 1909/12 JT(33)		
9	EA	39.2	#10, 131# SPG & Bolted Turnouts-Relay	$5,000.00	$45,000
2	EA	8.3	#7, 131# Bolted Turnouts-Relay	$3,500.00	$7,000
3	EA	9.0	#10, 100# Turnouts - Scrap	$240.00	$720
4	EA	10.4	#10, 90# Turnouts - Scrap	$205.00	$820
108	PR	6.2	133# 38" - 6 Hole JT. Bars - Scrap	$4.60	$497
			Drill = 6 - 6 - 7		
256	PR	14.7	131# 38" - 6 Hole JT. Bars - Scrap	$4.60	$1,178
			Drill = 6 1/2 - 6 1/2 - 6		
881	PR	33.7	131# 24" - 4 Hole Jt. Bars - Scrap	$3.05	$2,687
			Drill = Unk		
4,166	PR	133.3	100# 27" 4-Hole Angle Bars - Scrap	$2.55	$10,623
			Drill = 5 1/2 All		
2,713	PR	81.4	90# 27" 4-Hole Angle Bars - Scrap	$2.40	$6,511
			Drill = 5 1/2 All		
2,330	EA	25.0	Tieplates, 7 3/4 X 14" D.S. 6 Hole - Relay	$2.35	$5,476
24,460	EA	195.7	Tieplates, 7 3/4 X 12" D.S. 9 Hole Com-Relay	$2.00	$48,920
			On 90 & 100# Rail		
112,694	EA	563.5	Tieplates, 7 3/4 X 9 & 10" S.S. - Scrap	$0.40	$45,078
11,205	EA	11.2	Rail Anchors, Mixed - Relay	$0.35	$3,922
51,592	EA	51.6	Rail Anchors, Mixed - Scrap	$0.08	$4,127

Table G.9. Estimated Track Salvage Value of Hooper Junction-to-Pullman Line					
Winona-to-Colfax Segment: MP 52.00 To 78.10					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
1	LS	124.6	MISC. O.T.M.	$80.00	$9,967
Track Salvage Value of the Winona-Colfax Segment					**$1,188,610**
Source: *Wilbur Smith Associates, 1999*					

Table G.10. Estimated Track Removal Cost of Hooper Junction-to-Pullman Line				
Winona-to-Colfax Segment: MP 52.00 To 78.10				
Quantity	**Unit**	**Description of Item**	**Unit Price**	**Total Cost**
137,808	TF	Jointed Rail Removal	$1.65	$227,383
556	TF	Restore 14 Paved Public Road X-ings	$55.00	$30,580
416	TF	Restore 26 Unpaved Priv. Road X-ings	$10.00	$4,160
942	TF	Remove 11 Ea Timb Pile & Frame Trestles	$11.00	$10,362
468	TF	Remove 5 Ea Steel (DPG, TPG, ETC)	$115.00	$53,820
18,988	EA	Dispose Of Scrap Ties	$2.00	$37,976
Removal Cost of Track Assets in the Winona-to-Colfax Segment				**$364,281**
Source: *Wilbur Smith Associates, 1999*				

Colfax to Pullman

Table G.11 shows the estimated track salvage value of assets in the Colfax-to-Pullman segment of the line ($648,056). Table G.12 shows the estimated removal cost of these assets ($332,271). The estimated net liquidation value of this segment is $315,785.

Table G.11. Estimated Track Salvage Value of Hooper Junction-to-Pullman Line					
Colfax-to-Pullman Segment: MP 0.00 To 19.00					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
22,131	EA	0.0	Cross Ties - Reuseable	$5.00	$110,655
14,301	EA	0.0	Cross Ties - Landscape	$1.60	$22,882
8,554	LF	161.6	119# CW Rail - Relay(CL#1)	$500.00	$80,793
			119/0 CC CF & I 1957 CW(EL)		
1,267	LF	23.1	115# JT Rail - Relay(CL#1)	$450.00	$10,382
			115RE HH, VT Nippon Steel 1983 JT(39)		
10,560	LF	167.3	100# JT Rail - Scrap	$90.00	$15,054
			RE OH 100/25 ILL 1917/20 JT(33)		
180,259	LF	2,855.3	90# JT Rail - Scrap	$90.00	$256,977
			Colorado SEC 90ARA, 1915/23 OH JT(33)		
			OH CF & I CO 90 ARA, 1910 JT		
			ARA 90/20 ILL Steel S. WKS. 1915 JT(33)		
1	EA	4.1	#11, 115# RBM, 19-6 PTS New W/Pandrol	$25,000	$25,000
11	EA	28.6	#10, 90# Turnouts - Scrap	$205.00	$2,255
32	PR	1.6	115# 36" - 6 Hole JT. Bars - Scrap	$3.95	$126
			Drill = 6-6-7		

Table G.11. Estimated Track Salvage Value of Hooper Junction-to-Pullman Line					
Colfax-to-Pullman Segment: MP 0.00 To 19.00					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
270	PR	8.6	100# 27" 4-Hole Angle Bars - Scrap	$2.55	$689
			Drill = 5 1/2 All		
5,462	PR	163.9	90# 27" 4-Hole Angle Bars - Scrap	$2.40	$13,109
			Drill = 5 1/2 All		
0	PR	0.0	75# 24" 4-Hole Angle Bars - Scrap	$2.20	$-
0	PR	0.0	56-75# 24" 4-Hole Angle Bars - Scrap	$2.00	$-
5,416	EA	58.1	Tieplates, 7 3/4 X 14" D.S. 8 Hole - Relay	$2.55	$13,811
11,648	EA	125.0	Tieplates, 7 3/4 X 14" D.S. 9 Hole Com-Relay	$2.35	$27,373
11,648	EA	93.2	Tieplates, 7 3/4 X 12" D.S. 9 Hole Com-Relay	$2.00	$23,296
			On 90 & 100# Rail		
81,943	EA	409.7	Tieplates, 7 3/4 X 8 1/2" S.S. - Scrap	$0.40	$32,777
5,580	EA	5.6	Rail Anchors, Mixed - Relay	$0.35	$1,953
45,856	EA	45.9	Rail Anchors, Mixed - Scrap	$0.08	$3,668
1	LS	90.7	MISC. O.T.M.	$80.00	$7,256
Track Salvage Value of the Colfax-to-Pullman Segment					$**648,056**
Source: *Wilbur Smith Associates, 1999*					

Table G.12. Estimated Track Removal Cost of Hooper Junction-to-Pullman Line				
Colfax-to-Pullman Segment: MP 0.00 To 19.00				
Quantity	**Unit**	**Description of Item**	**Unit Price**	**Total Cost**
4,277	TF	Welded Rail Removal	$2.10	$8,982
96,043	TF	Jointed Rail Removal	$1.65	$158,471
616	TF	Restore 13 Paved Public Road X-Ings	$55.00	$33,880
320	TF	Restore 20 Unpaved Priv. Road X-Ings	$10.00	$3,200
3,786	TF	Remove 15 Ea Timb Pile & Frame Trestles	$11.00	$41,646
420	TF	Remove 3 Ea Steel (DPG, TPG, ETC)	$115.00	$48,300
18,896	EA	Dispose Of Scrap Ties	$2.00	$37,792
Removal Cost of Track Assets in the Colfax-to-Pullman Segment				$**332,271**
Source: *Wilbur Smith Associates, 1999*				

Winona to St. John

Table G.13 shows the estimated track salvage value of assets in the Winona-to-St. John segment of the line ($470,433). Table G.14 shows the estimated removal cost of these assets ($251,897). The estimated net liquidation value of this segment is $218,536.

Table G.13. Estimated Track Salvage Value of Hooper Junction-to-Pullman Line					
Winona-to-St. John Segment: MP 0.00 To 19.00					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
15,400	EA	0.0	Cross Ties - Reuseable	$5.00	$77,000
12,403	EA	0.0	Cross Ties - Reuseable	$8.00	$99,224

Table G.13. Estimated Track Salvage Value of Hooper Junction-to-Pullman Line					
Winona-to-St. John Segment: MP 0.00 To 19.00					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
15,490	EA	0.0	Cross Ties - Landscape	$1.60	$24,784
11,814	LF	261.9	133# JT Rail - Relay(CL#1)	$450.00	$117,862
			133/0 RE CC CF&I 1948/57 JT(39)		
			133/31 RE CC USS ILL. 1953/54 JT(39)		
4,540	LF	85.8	119# CW Rail - Relay(CL#1)	$500.00	$42,880
			119/0 CC CF & I 1956 CW(EL)		
4	EA	17.4	#10, 133# SPG & Bolted Turnouts-Relay	$5,000	$20,000
1	EA	2.9	#6, 132# RBM Turnout - Relay	$3,500	$3,500
6	EA	13.1	#10, 75# Turnouts - Scrap	$170.00	$1,020
302	PR	17.4	133# 38" - 6 Hole Jt. Bars - Scrap	$4.60	$1,389
			Drill = 6 - 6 - 7		
			Drill = 5 1/2 All		
5,705	PR	159.7	75# 24" 4-Hole Angle Bars - Scrap	$2.20	$12,551
6,348	EA	68.1	Tieplates, 7 3/4 X 14" D.S. 6 Hole - Relay	$2.35	$14,918
2,437	EA	24.1	Tieplates, 7 3/4 X 13" D.S. 8 Hole - Relay	$2.35	$5,727
			For 5 1/2" Base Rail		
90,954	EA	454.8	Tieplates, 7 3/4 X 9" S.S. - Scrap	$0.40	$36,382
9,300	EA	9.3	Rail Anchors, Mixed - Relay	$0.35	$3,255
34,230	EA	34.2	Rail Anchors, Mixed - Scrap	$0.08	$2,738
1	LS	90.0	MISC. O.T.M.	$80.00	$7,202
Track Salvage Value of the Winona-to-St. John Segment					**$470,433**
Source: *Wilbur Smith Associates, 1999*					

Table G.14 Estimated Track Removal Cost of Hooper Junction-to-Pullman Line				
Winona-to-St. John Segment: MP 0.00 To 19.00				
Quantity	**Unit**	**Description of Item**	**Unit Price**	**Total Cost**
2,270	TF	Welded Rail Removal	$2.10	$4,767
100,056	TF	Jointed Rail Removal	$1.65	$165,092
460	TF	Restore 13 Paved Public Road X-Ings	$55.00	$25,300
336	TF	Restore 21 Unpaved Priv. Road X-Ings	$10.00	$3,360
752	TF	Remove 11 Ea Timb Pile & Frame Trestles	$11.00	$8,272
190	TF	Remove 2 Ea Steel (DPG, TPG, ETC)	$115.00	$21,850
11,628	EA	Dispose Of Scrap Ties	$2.00	$23,256
Removal Cost of Track Assets in the **Winona-to-St. John Segment**				**$251,897**
Source: *Wilbur Smith Associates, 1999*				

St. John to Thornton

Table G.15 shows the estimated track salvage value of assets in the Winona-to-St. John segment of the line ($631,440). Table G.16 shows the estimated removal cost of these assets ($144,710). The estimated net liquidation value of this segment is $486,730. The NLV for the entire Hooper Jct-to-Pullman Line is $2,979,519 (Table G.17).

Table G.15. Estimated Track Salvage Value of Hooper Junction-to-Pullman Line					
St. John-to-Thornton Segment: MP 19.00 To 31.83					
Quantity	**Unit**	**Net Tons**	**Description of Item**	**Unit Price**	**Total Cost**
10,200	EA	0.0	Cross Ties - Reuseable	$5.00	$51,000
8,222	EA	0.0	Cross Ties - Reuseable	$8.00	$65,776
10,285	EA	0.0	Cross Ties - Landscape	$1.60	$16,456
3,696	LF	81.9	133# JT Rail - Relay(CL#1)	$450.00	$36,873
			133/0 RE CC CF&I 1954 JT(39)		
22,070	LF	457.7	131# JT Rail - Relay(CL#1)	$450.00	$205,979
			131/1 RE OH Colorado 1939/44 JT(36)		
7,603	LF	143.6	119# CW Rail - Relay(CL#1)	$500.00	$71,810
			119/0 CC CF & I 1957 CW(EL)		
102,326	LF	1,214.6	75# JT Rail - Scrap	$90.00	$109,315
			CF & I CO. SEC 75/4, 1907 JT(33)		
			Colorado SEC 75/7, 1912 OH JT(33)		
			75/13 ILL Steel CO. S. WKS 1898/1903 JT(33)		
1	EA	4.3	#10, 131# RBM Turnout - Relay	$4,000	$4,000
5	EA	10.9	#10, 75# Turnouts - Scrap	$170.00	$850
0	EA	0.0	#9, 66# Turnout - Scrap	$150.00	$-
95	PR	5.5	133# 38" - 6 Hole JT. Bars - Scrap	$4.60	$437
			Drill = 6 - 6 - 7		
566	PR	32.5	131# 24" - 4 Hole JT. Bars - Scrap	$4.60	$2,604
			Drill = 6 1/2 - 6 - 6 1/2		
3,101	PR	86.8	75# 24" 4-Hole Angle Bars - Scrap	$2.20	$6,822
			Drill = 5 1/2" All		
1,984	EA	21.3	Tieplates, 7 3/4 X 14" D.S. 6 Hole - Relay	$2.35	$4,662
4,080	EA	40.3	Tieplates, 7 3/4 X 13" D.S. 8 Hole - Relay	$2.35	$9,588
			For 5 1/2" Base Rail		
11,846	EA	94.2	Tieplates, 7 3/4 X 12" D.S. 8 Hole - Relay	$1.30	$15,400
			For 6" Base Rail		
49,430	EA	247.2	Tieplates, 7 3/4 X 9" S.S. - Scrap	$0.40	$19,772
10,948	EA	10.9	Rail Anchors, Mixed - Relay	$0.35	$3,832
18,606	EA	18.6	Rail Anchors, Mixed - Scrap	$0.08	$1,488
1	LS	59.7	MISC. O.T.M.	$80.00	$4,775
Track Salvage Value of the St. John-to-Thornton Segment					$**631,440**
Source: *Wilbur Smith Associates, 1999*					

Table G.16 Estimated Track Removal Cost of Hooper Junction-to-Pullman Line				
St. John-to-Thornton Segment: MP 19.00 To 31.83				
Quantity	**Unit**	**Description of Item**	**Unit Price**	**Total Cost**
3,802	TF	Welded Rail Removal	$2.10	$7,984
64,046	TF	Jointed Rail Removal	$1.65	$105,676
178	TF	Restore 5 Paved Public Road X-ings	$55.00	$9,790
208	TF	Restore 13 Unpaved Priv. Road X-ings	$10.00	$2,080

Table G.16 Estimated Track Removal Cost of Hooper Junction-to-Pullman Line				
St. John-to-Thornton Segment: MP 19.00 To 31.83				
Quantity	**Unit**	**Description of Item**	**Unit Price**	**Total Cost**
342	TF	Remove 5 Ea Timb Pile & Frame Trestles	$11.00	$3,762
7,709	EA	Dispose Of Scrap Ties	$2.00	$15,418
Removal Cost of Track Assets in St. John-to-Thornton Segment				**$144,710**
Source: *Wilbur Smith Associates, 1999*				

Table G.17. Summary of Net Liquidation Values of Hooper Jct.-to-Pullman Line	
Segment	**Net Liquidation Value**
Hooper Jct. to Winona	$1,134,139
Winona to Colfax	$824,329
Colfax to Pullman	$315,785
Winona to St. John	$218,536
St. John to Thornton	$486,730
Total NLV	**$2,979,519**

Zangar Junction-to-Walla Walla

An NLV was not estimated for the Zangar Junction-to-Walla Walla line during the 1998-1999 field studies. An estimated has been derived from track assets and 1999 unit prices (Table G.18). This segment has 27.5 miles of heavy jointed rail, 16 mainline turnouts, and 2,900 timber cross ties per mile. The estimated track salvage value of these assets is $2,055,643. The estimated liquidation value net of removal cost is $1,438,950.

Table G.18. Estimated Net Liquidation Value of Zangar Junction-to-Walla Walla Line Segment			
Track Material	**Units***	**Price**	**Value**
112/1 RE OH Colorado 1940/42 Jt(39) = 3.0 to 5.3	453	$250.00	$113,344
Colorado Sec. 110 RE 1929/31 Jt(39) = 5.3 to 15.2	1,917	$250.00	$479,160
131/28 RE OH Ill. 1945 Jt(39) = 15.2 to 30.5	3,528	$250.00	$881,892
Timber Cross Ties	2,900	$3.50	$279,606
Tie Plates	159,775	$1.55	$247,651
Joint Bars	8,123	$4.00	$32,492
Rail Anchors	79,888	$0.20	$15,978
Turnouts	16	$345.00	$5,520
Track Salvage Value			$2,055,643
Removal Cost			$616,693
Net Liquidation Value			$1,438,950
*Tons, per-mile, or each			

Summary of Estimated Net Liquidation Values

Table G.19 summarizes the estimated net liquidation values. Including the Zangar Junction-to-Walla Walla line, the total estimated NLV is $9,857,092 or $30,640 per mile. However, the Zangar Junction-to-Walla Walla line is owned by UP and leased to PCC. Technically, it is not part of the railroad's NLV. If the Zangar Junction-to-Walla Walla line is excluded from the calculation, the estimated NLV drops to $8,418,141 or $28,613 per mile.

Table G.19. Summary of Estimated Net Liquidation Values of PCC Rail Lines

Line Segment	**Miles**	**Net Liquidation Value**	**NLV per Mile**
Hooper Jct. to Winona	26.75	$1,134,139	$42,398
Winona to Colfax	26.10	$824,329	$31,583
Winona to St. John	19.00	$218,536	$11,502
St. John to Thornton	12.85	$486,730	$37,878
Colfax to Pullman	19.00	$315,785	$16,620
Marshall to Moscow	83.05	$3,644,512	$43,883
Cheney to Coulee City	107.46	$1,794,110	$16,696
Zangar Jct. to Walla Walla	27.50	$1,438,950	$52,325
Total	**321.71**	**$9,857,092**	**$30,640**

Appendix H. Pavement Impact Methods and Equations

The purpose of this appendix is to provide greater documentation of the analytical methods used in this chapter. The topics covered include:

- Comparison of functional class and generic paving costs;
- Background concepts relevant to pavement impact analysis;
- Axle load equivalency factors developed by the American Association of State Highway and Transportation Officials; and
- The equations and formulas used to estimate the lives and deterioration rates of pavements.

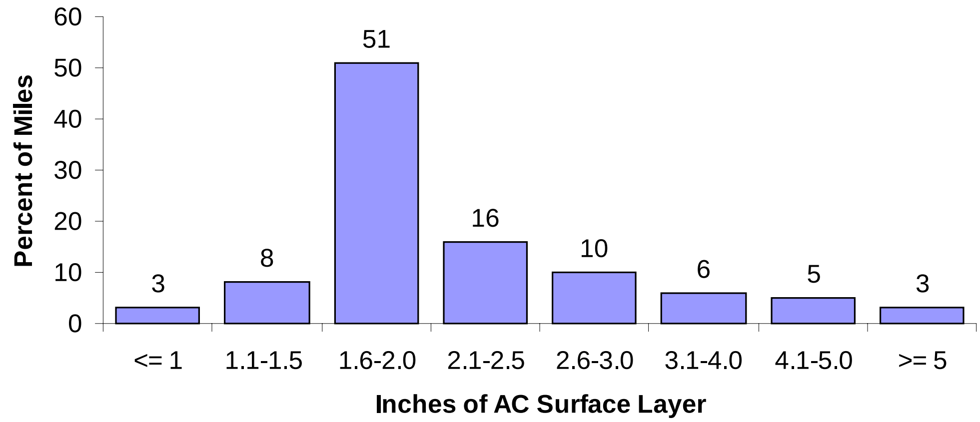
Comparison of resurfacing unit costs and WSDOT generic paving costs

In this chapter, resurfacing unit costs were developed for functional classes of highways in Washington. There is a strong relationship between the functional class costs shown in Table 10 of this chapter and the typical Washington State Department of Transportation (WSDOT) paving cost shown in Table 7 of this chapter.

Figure 1 shows a weighted distribution of top layer thicknesses for more than a thousand rural highway segments in eastern Washington.[1] The distribution was derived from the 2001 database. As Figure 1 shows, 51 percent of the rural highway miles in eastern Washington with asphalt-concrete surfaces have surface layer thicknesses of 1.6 to 2.0 inches.[2] Another 16 percent of these rural highway miles are surfaced to a depth of 2.1 to 2.5 inches. Ten percent of these highway miles have surface layers of 2.6 to 3.0 inches. Another 14 percent have AC surface layers of 3.1 inches or more. However, 8 percent of these rural asphalt-concrete pavement (ACP) miles have surface layers of 1.1 to 1.5 inches. The remaining 3 percent have surface layers of 1-inch or less.

[1] For purposes of this illustration, eastern Washington is defined as the North Central, South Central, and Eastern Regions, corresponding to district codes 2, 5, and 6 in the WSPMS database.
[2] The median and mode of the distribution is 1.8 inches.

Figure 1. Asphalt-Concrete Surface Layer Thicknesses of Rural Highways in Eastern Washington



The distribution of surface layer thicknesses shown in Figure 1 illustrates the variation that exists in pavement restoration costs among functional classes. A numerical analysis of pavements in eastern Washington highlights the relationship between the generic paving costs and the functional class costs shown in the report. In this comparison, a weighted-average resurfacing cost is computed from the unit costs shown in Table 10 in Chapter 2 using WSPMS data. The WSPMS database includes 1,240 rural (ACP) segments in eastern Washington. The lane-miles, terrain type, and functional class are coded for each highway segment. Using this information, the estimated resurfacing cost in eastern Washington—weighted by lane miles—is $110,000 per lane-mile. As expected, this estimate is very close to the WSDOT rural paving cost of $110,000 to $112,000 per lane-mile.

Background concepts in pavement impact analysis

The methods used in this study are based on equations that relate the physical lives of pavements to axle loads. They were developed originally from road test data. Later, they were incorporated into the pavement design procedures developed by the American Association of State Highway and Transportation Officials (AASHTO).

Pavement damage functions

The deterioration of pavements can be analyzed with a damage function that relates decline in pavement serviceability to traffic or axle passes. This general relationship is expressed by Equation 1.

Equation 1

$$g = \left(\frac{N}{\tau}\right)^{\beta}$$

where:

- g = an index of damage or deterioration
- N = the number of passes of an axle group of specified weight and configuration (e.g., a single 18,000-pound axle)
- τ = the number of axle passes at which the section reaches failure; i.e., the theoretical life of the pavement
- β = a deterioration rate that describes a deterioration curve; i.e., a shape factor

At any time between construction (or replacement) and pavement failure, the value of g (the damage index) will range between 0.0 and 1.0. When N equals zero for a newly-constructed or rehabilitated section, g equals zero. However, when N (the number of cumulative axle passes) equals the life of a highway section (τ), g equals 1.0.

One way to measure accumulated pavement damage or distress is through a serviceability index. A pavement serviceability rating is a composite index that reflects the general serviceability of pavements at the time of evaluation. The useful life of a pavement can be expressed as the maximum tolerable decline in serviceability rating before a pavement is restored or rehabilitated. Two other useful measures, expired pavement life since construction and remaining pavement life until rehabilitation, frequently are expressed as ranges in pavement serviceability ratings. If the ratio of decline in pavement serviceability relative to the maximum tolerable decline in serviceability is used to represent the damage index, then Equation 1 may be rewritten as follows:

Equation 2

$$\frac{P_I - P}{P_I - P_T} = \left(\frac{N}{\tau}\right)^{\beta}$$

where:

- P_I = Initial pavement serviceability rating
- P_T = Terminal pavement serviceability rating
- P = Current or present serviceability rating

The term P_I - P on the left-hand side of the equation represents the decline in pavement serviceability rating from the time the highway was initially constructed (or replaced) until the present. The denominator in the expression (P_I - P_T) represents the total decline in pavement serviceability that is possible from the time the pavement is built (or replaced) until it reaches failure (terminal serviceability).

Pavement serviceability ratings

AASHTO developed the Pavement Serviceability Index (PSI) to track pavement deterioration on road test sections. The PSI is a composite index (scaled 0 to 5) that reflects the extent to which certain physical distresses affect the serviceability of a pavement section. In the road test, four major distresses were reflected in the computed PSI values for flexible pavements: cracking, patching, slope variance or longitudinal roughness, and rut depth.

A similar but qualitative rating scheme, the PSR is used in Highway Economic Requirement System (HERS). As Table 1 depicts, PSR considers the smoothness of the ride as well as the extent of rutting and other distresses. By modeling a decline in PSR, one is, to a certain extent, modeling the occurrence of individual distresses as well. The relationship between PSR and Pavement Structural Condition (PSC) is discussed in this chapter.

Table 1. Present Serviceability Rating Scale

PSR	Verbal Rating	Description
5	Very Good	Only new (or nearly new) pavements are likely to be smooth enough and sufficiently free of cracks and patches to qualify for this category. All pavements constructed or resurfaced recently should be rated very good.
4	Good	Pavements in this category, although not quite as smooth as those described above, give first-class ride and exhibit few, if any visible signs of surface deterioration. Flexible pavements may be beginning to show evidence of rutting and fine random cracks. Rigid pavements may be beginning to show evidence of slight surface deterioration, such as minor cracks and spalling.
3	Fair	The riding qualities of pavements in this category are noticeably inferior to those of new pavements, and may be barely tolerable for high-speed traffic. Surface defects of flexible pavements may include rutting, map cracking, and more or less extensive patching. Rigid pavements in this group may have a few joint failures, faulting and cracking, and some pumping.
2	Poor	Pavements that have deteriorated to such an extent that they are in need of resurfacing.
1	Very Poor	Pavements that are in an extremely deteriorated condition and may even need complete reconstruction.

Source: *USDOT, Status of the Nation's Highways, July, 1983.*

AASHTO road test damage functions

During the road test, accumulated traffic and axle loads were statistically related to changes in PSI. Each highway section was evaluated at two-week intervals. From the occurrence of distresses, a current PSI was calculated.

Given the current PSI and the cumulative axle loads, the value of the damage index (g) was calculated (for each test section) based on the original and terminal PSI. The unknown parameters in the equation (β and τ) were estimated through regression analysis. The form of the regression equation for each parameter is given by Equations 3 and 4, respectively.

Equation 3

$$\log_{10}(\tau) = 5.93 + 9.36 \log_{10}(\mathrm{SN} + 1) \\ - 4.79 \log_{10}(\mathrm{L}_1 + \mathrm{L}_2) + 4.33 \log_{10}(\mathrm{L}_2)$$

Equation 4

$$\beta = 0.4 + \frac{0.081(\mathrm{L}_1 + \mathrm{L}_2)^{3.23}}{(\mathrm{SN} + 1)^{5.19}\,\mathrm{L}_2^{3.23}}$$

Where:

β = Rate of deterioration for a given axle
L_1 = Axle load in thousand-pounds or kips
L_2 = Axle type [L_2 =1 for a single axle, L_2 =2 for a tandem axle, and L_2 =3 for triple or tridem axles]

Substituting "18" for L_1 and "1" for L_2 in Equation 3 yields:

Equation 5

$$\log_{10}(\tau) = 9.36 \log_{10}(\mathrm{SN} + 1) - 0.2$$

Equation 5 is the theoretical life of a pavement in 18,000-pound axle loads, or N in Equation 2.

In the next section of the appendix, the AASHTO road test results and equations are used to develop axle load equivalency factors for different truck and axle configurations.

Axle load equivalency factors

The effects of different truck axle configurations on pavements are estimated by converting all axle loads to equivalent single axle loads (ESALs). In this chapter, an ESAL represents the equivalent pavement impact of an axle load as compared to a single 18,000-pound axle. For example, an axle with an ESAL factor of 1.2 has 1.2 times the impact of a single 18,000-pound axle.

The steps in computing ESALs are: (1) compute the rate of pavement deterioration for the reference axle, (2) compute the rate of pavement deterioration for an axle load of interest, and (3) use the deterioration rates to compute a load equivalency factor. The ESAL or load equivalency factor of an axle group depends upon the type of axle (single, tandem, or tridem), the load on the axle in thousands of pounds (kilo-pounds or kips), the type of pavement section (flexible or rigid), and the terminal serviceability rating of the pavement (p_t).

Flexible ESAL formulas

Substituting "18" for L_1 and "1" for L_2 in Equation 4 yields the rate of flexible pavement deterioration for the reference axle (the single 18,000-pound axle), as shown in Equation 6.

Equation 6

$$\beta_{18} = 0.4 + \frac{1{,}094}{(\mathrm{SN}+1)^{5.19}}$$

Where:

β_{18} = Rate of deterioration for a single 18-kip axle load
SN = Structural number of flexible pavement section

Expressions for axle load equivalency factors or ESALs can be derived for any range in PSR decline by substitution into Equation 2. Substituting Equation 3 for τ, Equation 5 for N, and Equation 6 for β gives a damage factor for an 18-kip axle load. Alternatively, specifying L_1 and L_2 in Equation 4, and substituting Equation 4 for β in Equation 2, gives a damage factor for an axle type and load. The solution of these equations yields a formula for computing the equivalent rate of flexible pavement deterioration caused by a single-axle load in comparison to an 18-kip axle load (Equation 7).

Equation 7

$$\log_{10}(\text{ESAL}) = 4.79\ \log_{10}\left(\frac{L_1 + 1}{18 + 1}\right) + \frac{G}{\beta_{18}} - \frac{G}{\beta}$$

Another derived formula, Equation 8, computes the equivalent rate of flexible pavement deterioration caused by a given tandem-axle group:

Equation 8

$$\log_{10}(\text{ESAL}) = 4.79\ \log_{10}\left(\frac{L_1 + 2}{18 + 1}\right) - 4.33\ \log_{10}(2) + \frac{G}{\beta_{18}} - \frac{G}{\beta}$$

In both formulas, G is computed as:

Equation 9

$$G = \log_{10}\left(\frac{P_1 - P_T}{P_1 - 1.5}\right)$$

Since the solutions to Equations 7 and 8 result in logarithms, the actual ESAL factors n are computed by taking the inverse logarithm of the appropriate expression, as shown in Equation 10.

Equation 10

$$n = 10^{\log_{10}(\text{ESAL})}$$

Rigid ESAL formulas

From AASHTO road test data, the rate of rigid pavement deterioration caused by a single 18,000-pound axle is given by Equation 11.

Equation 11

$$\beta_{18} = 1 + \frac{3.63(19)^{5.2}}{(d + 1)^{8.46}}$$

where d = pavement thickness in inches.

The rate of deterioration for the all other axle loads on rigid pavement can be expressed as:

Equation 12

$$\beta = 1 + \frac{3.63\left(L_1 + L_2\right)^{5.2}}{\left(d+1\right)^{8.46} L_2^{3.52}}$$

A formula for computing the equivalent rate of rigid pavement deterioration caused by a given single-axle group is obtained by combining and simplifying previous equations. The solution (shown in Equation 13) is used to convert rates of deterioration to rigid ESALs for single-axle loads.

Equation 13

$$\log_{10}\left(\mathrm{ESAL}\right) = 4.62\ \log_{10}\left(\frac{L_1 + 1}{18+1}\right) + \frac{G}{\beta_{18}} - \frac{G}{\beta}$$

Similarly, Equation 14 computes the equivalent rate of rigid pavement deterioration caused by a given tandem-axle group.

Equation 14

$$\log_{10}\left(\mathrm{ESAL}\right) - 4.62\ \log_{10}\left(\frac{L_1 + 2}{18+1}\right) - 3.28\ \log_{10}\left(2\right) + \frac{G}{\beta_{18}} - \frac{G}{\beta}$$

The term G in Equation 14 is computed as:

Equation 15

$$G = \log_{10}\left(\frac{P_1 - P_T}{P_1 - 1.5}\right)$$

Finally, the number of ESALs generated by an axle load over a rigid pavement section is given by the inverse logarithm of the appropriate expression:

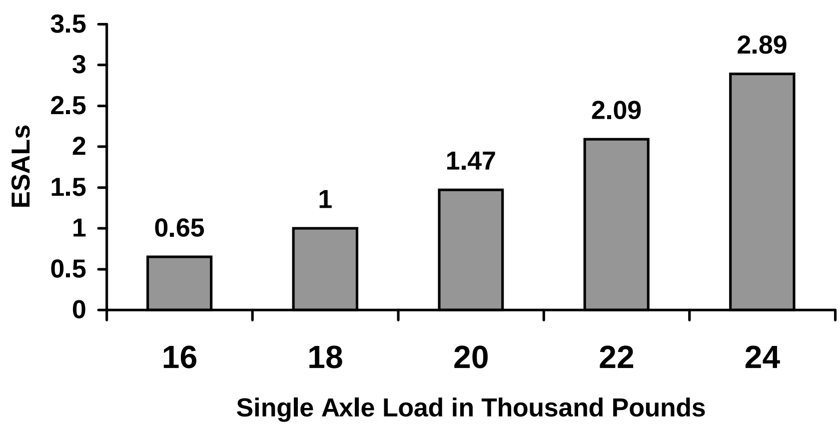
Equation 16

$$n = 10^{\log_{10}\left(\mathrm{ESAL}\right)}$$

Illustration of AASHTO ESAL factors

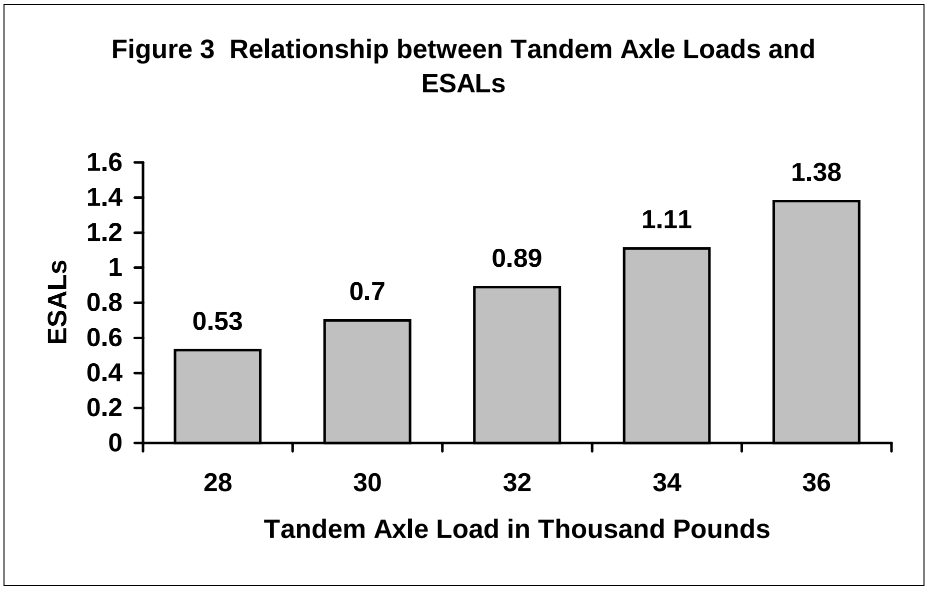
Figure 2 illustrates the impacts of single-axle loads on a medium strength flexible pavement with a terminal serviceability of 2.5. The chart illustrates several relationships. First, a 16,000-pound single-axle load followed by a 20,000-pound single-axle load generates a total of 2.115 ESALs as compared to two ESALs for the passage of two 18,000-pound single axles. In essence, load distribution among axles is important in pavement impact analysis. Second, an increase in a single-axle load from 18,000 to 22,000 pounds more than doubles the pavement impact. In general, the ESAL factor for a given type of axle increases with the fourth power of the axle load. Consequently, even modest illegal overloads (e.g., 22,000 pounds on a single axle) can significantly increase pavement damage.

Figure 2 Relationship between ESALs and Axle Load for Single Axles



Pavement Damage is Approximately a 4th-Power of Axle Weight

Figure 3 illustrates the impacts of a tandem axle set on the same type of pavement. As the chart shows, 34,000 pounds on a tandem axle generates only 1.11 times the damage of 18,000 pounds on a single axle.



A Weight of 32,000 Pounds on a Tandem Axle Has Less Pavement Impact Than 18,000 Pounds on a Single Axle

ESAL life functions

ESAL life is an important input to the average/marginal cost method of estimating pavement costs. The ESAL life of a pavement is the cumulative number of equivalent single-axle loads that the pavement can accommodate before it is rehabilitated.

Flexible pavements

The formula for computing the ESAL life of a flexible pavement is presented in Equations 17 through 22. For purposes of simplification, the lengthy function is organized into four terms, shown in Equation 17.

Equation 17

$$\mathrm{LGE} = \mathrm{XA} + \frac{\mathrm{XG}}{\mathrm{XB}}$$

LGE represents the cumulative ESALs that a pavement section can accommodate before reaching its terminal serviceability rating (expressed in common logarithms). The term XB describes the rate at which a pavement's life is consumed with the accumulation of ESALs. XB is a function of the structural number as reflected in the term SNA of Equation 18.

Equation 18

$$SNA = SN + \sqrt{\frac{6}{SN}}$$

Equation 19

$$XB = 0.4 + \left(\frac{1{,}094}{SNA}\right)^{5.19}$$

XG expresses pavement serviceability loss in terms of the maximum tolerable decline in PSR (from P_I to P_T). If the maximum PSR loss is 3.5 (e.g., from 5.0 to 1.5), then XG equals zero and the term XG/XB in Equation 17 equals zero. In essence, the theoretical life of a newly constructed pavement in ESALs is given by Equation 21.

Equation 20

$$XG = \log_{10}\left(\frac{P_1 - P_T}{3.5}\right)$$

Equation 21

$$XA = 9.36\ \log_{10}(SNA) - 0.2$$

Since the result of Equation 21 is expressed in logarithms, the actual life-cycle is computed by taking the inverse log:

Equation 22

$$ESALlife = 10^{LGE}$$

As Equation 22 shows, the theoretical life of a pavement is directly related to strength or structural number. However, the rate of pavement decay is inversely related to strength, as shown in Equation 19. Intuitively, both relationships make sense.

In reality, pavements are frequently restored or rehabilitated before their PSR values decline to 1.5. Consequently, their theoretical lives are rarely realized. In such instances, the solution of XG is negative and the ratio XA/XG adjusts the predicted ESAL life downward from its theoretical maximum. For example, the predicted ESAL life of a flexible pavement with a SN of 5.3 is approximately 21 million when the PSR is allowed to decline from 5.0 to 1.5, but only 10.4 million when the terminal PSR is 2.5.

Rigid pavements

The theoretical life of a rigid pavement is a function of the thickness of the concrete slab d.

Equation 23

$$XA = 7.35\ \log_{10}(d+1)0.06$$

The rate of traffic-related pavement deterioration of rigid pavements is given by:

Equation 24

$$XB = 1 + \frac{1{,}624{,}000}{(d+1)^{8.46}}$$

The maximum serviceability loss or economic life of a rigid pavement, in comparison to its maximum tolerable decline in PSR, is given by:

Equation 25

$$XG = \log_{10}\frac{(P_1 - P_T)}{3.5}$$

The logarithm of the expected ESAL life of a rigid pavement is computed as:

Equation 26

$$LGE = XA + \frac{XG}{XB}$$

Finally, the life cycle of a rigid pavement is computed by taking the inverse logarithm of LGE.

Equation 27

$$ESALlife = 10^{LGE}$$

Structural numbers of flexible pavements

The structural contributions of the pavement layers are additive, as illustrated in Equation 28.

Equation 28

$$SN = a_1 d_1 + a_1^* d_1^* + a_2 d_2 + a_3 d_3$$

where:

d_1 = Thickness of surface course (inches)
a_1 = Surface layer coefficient
d_1^* = Thickness of old surface layer as a base course (inches)
a_1^* = Layer coefficient of old surface course
d_2 = Thickness of base (inches)
a_2 = Base layer coefficient
d_3 = Thickness of subbase (inches)
a_3 = Subbase layer coefficient

Many flexible pavements have been rehabilitated since the original date of construction. When an overlay is placed on a pavement, the old surface layer becomes a base layer and continues to makes a structural contribution. The term a_1^* in the previous equation indicates that the old surface layer is still in-place and has not been recycled.

Layer coefficients

In this analysis, the composition of materials in each pavement layer and the depth of each layer have been derived from the WSPMS database. Layer coefficients have been used to convert the layer depths into structural numbers.

Layer coefficients for asphalt-concrete surface layers and other common layer materials are shown in Table 2, with one exception: coefficients for asphalt-concrete layers that have been overlain with new surface layers are shown in Table 3. As shown in Table 3, old (overlaid) AC surface layers that exhibit little or no cracking are generally assigned a relatively high coefficient (e.g., .37). Old AC layers that exhibit less than 10 percent low-severity alligator cracking are assigned a coefficient of .25 to .35, and so forth.

The extent of accumulated distress on old AC surface layers at the times they were overlaid is not recorded in the WSPMS. Thus, the time interval between placement of layers is used as a proxy for accumulated distress. If the layer was 8 years old or less at the time it was overlaid, it is given a coefficient of .37. Older AC layers are assigned coefficients as follows:[3]

- 8 to 15 years: 0.28
- 15 to 20 years: 0.24
- > 20 years: 0.18

Table 2. Layer Coefficients Used to Compute Pavement Structural Numbers

Material	Layer Description	Layer Coefficient
Asphalt Concrete	New Top Surface Course	.44
Asphalt Concrete	Worn Top Surface Course	.37
Bituminous Surface Treatment	Surface Course	.24
Crushed Stone	Surface Course	.15
Crushed Stone	Base Course	.14
Portland Concrete Cement	Old Base	.40
Cement Treated Base	Base	.18
Gravel	Subbase	.11

Table 3. Suggested Layer Coefficients for Existing Asphalt-Concrete Surface Layers

Surface Condition	Coefficient
Little or no alligator cracking and/or only low-severity transverse cracking	0.35 to 0.40
< 10 percent low-severity alligator cracking and/or < 5 percent medium- and high-severity transverse cracking	0.25 to 0.35
> 10 percent low-severity alligator cracking and/or < 10 percent medium-severity alligator cracking and/or > 5-10 percent medium- and high-severity transverse cracking	0.20 to 0.30
> 10 percent medium-severity alligator cracking and/or < 10 percent high-severity alligator cracking and/or > 10 percent medium- and high-severity transverse cracking	0.14 to 0.20
> 10 percent high-severity alligator cracking and/or > 10 percent high-severity transverse cracking	0.08 to 0.15

Source: *American Association of State Highway and Transportation Officials. AASHTO Guide for Design of Pavement Structures, 1993.*

When Highway Performance Monitoring System (HPMS) sample segments overlap WSPMS segments, the structural numbers from the

[3] Allowances are made for higher functional classes and for very thin layers.

HPMS segments are substituted for the computed structural numbers for the WSPMS segments for simple two-lane highways. Presumably, the structural numbers for the HPMS segments reflect detailed data about conditions and accumulated distresses of old AC surface layers. Moreover, the longer segments provide greater continuity for the impact analysis.

Heavy truck user fees

Trucks generate many user fees. Therefore, incremental truck traffic will increase revenues to federal and state highway trust or special revenue funds. These revenues can be used by federal or state governments to make improvements to potentially-impacted highway sections. Incremental highway revenues include the following sources: (1) diesel fuel taxes, (2) registration and license fees, (3) federal excise taxes, and (4) heavy vehicle user taxes. Table 4 describes this system of truck user charges.

The Federal Vehicle Excise Tax only applies to heavy trucks operating at 26,000 pounds or greater. It is a one-time charge assessed on new vehicle sales. The Federal Heavy Vehicle Use Tax, which is paid each year, is a maximum of $550 per truck. The Washington State excise fee has been eliminated. However, the state heavy tonnage fee still applies. It is a fee of $250 per month that is applicable for each month of the year during which the truck makes at least one trip. For purposes of this study, the fee is assumed to apply during all 12 months.

Incremental revenues are estimated for each trip by prorating the vehicle registration and excise taxes on the basis of annual vehicle-miles of travel (VMT). It is assumed that the average combination truck accumulates 75,000 miles per year. Since the federal excise tax is a one-time charge per truck, this fee is apportioned on the basis of the estimated lives of the tractor and trailer units. Fuel tax revenues also are estimated on a vehicle-mile basis, assuming an average fuel consumption rate of 5.5 miles per gallon.

Table 4. Estimated Truck Use Revenues per Vehicle Mile of Travel for Rocky Mountain Double	
Tax and Use Rates	**Values**
Miles per Gallon	5.5
Fuel Tax Revenue per VMT	$0.0862
Retail Cost: New Tractor	$75,000
Vehicle Excise Tax: Tractor	$9,000
Useful Life of Tractor (Miles)	500,000
Retail Cost: New Trailers	$35,000
Vehicle Excise Tax: Trailers	$4,410
Useful Life of Trailers (Miles)	750,000
Vehicle Excise Tax per VMT	$0.0239
Tire Excise Tax	$207
Tire Life (Miles)	150,000
Tire Tax per VMT	$0.0014
Annual Miles	75,000
Heavy User Tax per VMT	$0.0073
State Heavy Tonnage Fee per VMT	$0.0400
State Over-Length Permit Fee per VMT	$0.0013
Total Fees per VMT	$0.0739
Total Fuel & Fees per VMT	$0.1601

Appendix I. Detailed Results for Individual Highway Segments

The purpose of this appendix is to present results for individual highway segments. These detailed tables may provide insights as to how the projected costs vary with the characteristics of potentially-impacted segments. The results of the analysis can also be summarized by region/district.

Build-sooner costs

Summaries and examples of build-sooner cost were presented in the report. Table 1 shows the estimated difference in due years and present value of resurfacing costs for individual highway segments. Only those highway segments for which for the resurfacing interval is shortened are shown in the table. The current PSC and PSR are shown for each segment.

Table 1. Estimated Build-Sooner Cost for Asphalt-Concrete Pavements Impacted by Potential Abandonment

Route	Beginning Milepost	Ending Milepost	PSC	PSR	Year Due: WSPMS	Predicted Year: Base	Predicted Year: Impact	Difference in Present Value of Cost
2	214.76	214.86	84	4.0	2005	2005	2002	$2,484
2	214.86	214.88	90	4.2	2006	2006	2002	$649
2	214.88	215.06	90	4.2	2006	2006	2002	$5,839
2	215.06	220.88	90	4.2	2007	2007	2002	$231,205
2	220.88	221.19	99	4.5	2009	2016	2012	$6,582
12	363.95	364.06	100	4.5	2009	2010	2009	$706
12	364.06	364.07	100	4.5	2009	2010	2009	$64
12	364.07	364.23	100	4.5	2009	2010	2009	$1,027
12	366.30	366.42	100	4.5	2009	2009	2008	$803
12	366.42	366.51	100	4.5	2009	2009	2008	$602
12	367.55	367.59	100	4.5	2009	2017	2016	$191
17	7.48	7.59	100	4.5	2010	2016	2015	$547
17	7.59	7.67	100	4.5	2009	2015	2014	$415
17	10.32	11.10	92	4.3	2005	2016	2015	$3,881
17	33.07	33.43	100	4.5	2010	2010	2009	$2,310
17	34.24	34.30	100	4.5	2010	2010	2009	$385
17	39.74	39.86	100	4.5	2010	2010	2009	$770
17	39.86	40.24	100	4.5	2010	2010	2009	$2,438
17	48.28	48.64	100	4.5	2010	2010	2009	$2,310
17	53.91	54.24	99	4.5	2011	2011	2010	$2,947

Table 1. Estimated Build-Sooner Cost for Asphalt-Concrete Pavements Impacted by Potential Abandonment								
Route	**Beginning Milepost**	**Ending Milepost**	**PSC**	**PSR**	**Year Due: WSPMS**	**Predicted Year: Base**	**Predicted Year: Impact**	**Difference in Present Value of Cost**
17	54.58	54.89	100	4.5	2011	2011	2010	$2,768
17	54.89	54.99	100	4.5	2011	2011	2010	$1,514
17	55.68	55.86	97	4.4	2014	2014	2013	$2,399
17	55.86	56.25	99	4.5	2011	2011	2010	$4,659
17	56.91	57.87	98	4.4	2014	2014	2013	$7,548
17	57.87	58.83	98	4.4	2014	2014	2013	$7,548
17	59.02	59.13	98	4.4	2014	2014	2013	$865
17	91.60	92.22	93	4.3	2006	2006	2005	$4,713
17	92.22	92.56	61	3.3	2004	2004	2003	$2,813
17	94.45	94.57	82	4.0	2005	2005	2004	$952
17	94.57	94.83	83	4.0	2004	2004	2002	$4,396
17	94.83	95.06	83	4.0	2003	2003	2002	$1,985
17	95.06	95.99	83	4.0	2006	2006	2003	$22,141
17	95.99	96.57	83	4.0	2006	2006	2004	$9,009
21	24.20	24.37	100	4.5	2014	2014	2008	$6,157
21	24.37	24.45	100	4.5	2014	2014	2007	$3,456
21	26.49	26.60	82	4.0	2006	2006	2003	$2,619
21	26.60	26.75	75	3.8	2005	2005	2002	$3,726
21	55.83	55.90	74	3.7	2005	2005	2002	$1,739
21	55.90	55.96	74	3.7	2005	2005	2002	$1,490
21	55.96	56.03	72	3.7	2005	2005	2002	$1,739
21	56.03	56.15	70	3.6	2004	2004	2002	$2,029
21	56.15	56.27	75	3.8	2005	2005	2002	$2,981
21	56.27	56.36	85	4.1	2007	2007	2003	$2,798
21	91.35	91.72	92	4.3	2009	2009	2007	$5,061
21	91.72	91.73	95	4.4	2011	2011	2009	$126
21	91.73	91.78	95	4.4	2011	2011	2009	$628
23	14.02	14.23	69	3.6	2003	2003	2002	$1,813
23	14.23	14.36	78	3.8	2004	2004	2002	$2,198
23	14.36	14.41	78	3.8	2003	2003	2002	$432
26	116.92	117.20	100	4.5	2009	2014	2011	$4,749
26	116.92	117.20	100	4.5	2009	2014	2010	$6,471
26	117.20	117.22	100	4.5	2009	2009	2007	$274
26	117.20	117.22	100	4.5	2009	2009	2007	$274
26	117.22	117.89	100	4.5	2009	2009	2007	$9,164
26	117.22	117.89	100	4.5	2009	2009	2007	$9,164
26	117.89	118.10	100	4.5	2009	2009	2008	$1,406
26	117.89	118.10	100	4.5	2009	2009	2008	$1,406
26	118.10	119.09	100	4.5	2009	2009	2007	$13,541
26	118.10	119.09	100	4.5	2009	2009	2007	$13,541
26	119.09	119.14	100	4.5	2009	2009	2008	$335

Table 1. Estimated Build-Sooner Cost for Asphalt-Concrete Pavements Impacted by Potential Abandonment								
Route	**Beginning Milepost**	**Ending Milepost**	**PSC**	**PSR**	**Year Due: WSPMS**	**Predicted Year: Base**	**Predicted Year: Impact**	**Difference in Present Value of Cost**
26	119.09	119.14	100	4.5	2009	2009	2007	$684
26	119.14	119.16	100	4.5	2009	2009	2008	$134
26	119.14	119.16	100	4.5	2009	2009	2008	$134
26	119.16	123.27	100	4.5	2009	2009	2008	$27,512
26	119.16	123.27	100	4.5	2009	2009	2008	$27,512
26	123.27	123.69	100	4.5	2009	2009	2008	$2,811
26	123.69	124.01	100	4.5	2009	2009	2007	$4,377
26	123.69	124.01	100	4.5	2009	2009	2007	$4,377
26	124.01	124.88	100	4.5	2009	2009	2008	$5,824
26	124.88	124.94	100	4.5	2009	2009	2008	$402
26	124.88	124.94	100	4.5	2009	2009	2008	$402
26	124.94	124.99	100	4.5	2009	2009	2008	$335
26	124.94	124.99	100	4.5	2009	2009	2008	$335
26	124.99	125.16	100	4.5	2009	2009	2008	$1,138
26	124.99	125.16	100	4.5	2009	2009	2008	$1,138
26	125.16	125.26	100	4.5	2008	2008	2006	$1,427
26	125.16	125.26	100	4.5	2008	2008	2005	$2,187
26	125.26	125.27	97	4.4	2007	2007	2006	$73
26	125.26	125.27	97	4.4	2007	2007	2005	$149
26	125.27	125.89	97	4.4	2007	2007	2006	$4,517
26	125.27	125.89	97	4.4	2007	2007	2005	$9,231
26	125.89	125.90	65	3.5	2009	2009	2007	$137
26	125.89	125.90	65	3.5	2009	2009	2007	$137
26	125.90	126.05	65	3.5	2009	2009	2007	$2,052
26	125.90	126.05	65	3.5	2009	2009	2007	$2,052
26	126.05	126.06	77	3.8	2009	2009	2008	$67
26	126.05	126.06	77	3.8	2009	2009	2008	$67
26	126.06	126.33	77	3.8	2009	2009	2008	$1,807
26	126.06	126.33	77	3.8	2009	2009	2008	$1,807
26	126.33	126.41	73	3.7	2009	2009	2008	$536
26	126.33	126.41	73	3.7	2009	2009	2007	$1,094
26	126.41	128.08	88	4.1	2009	2009	2008	$11,179
26	126.41	128.08	88	4.1	2009	2009	2008	$11,179
26	128.08	129.56	74	3.7	2009	2009	2008	$9,907
26	128.08	129.56	74	3.7	2009	2009	2008	$9,907
26	132.28	132.94	96	4.4	2009	2013	2012	$3,729
26	132.28	132.94	96	4.4	2009	2013	2011	$7,619
27	0.00	0.11	100	4.5	2011	2012	2008	$4,018
27	0.11	0.24	93	4.3	2008	2008	2007	$1,318
27	1.39	1.45	100	4.5	2011	2011	2010	$536
27	1.45	1.52	97	4.4	2010	2010	2009	$652

Table 1. Estimated Build-Sooner Cost for Asphalt-Concrete Pavements Impacted by Potential Abandonment								
Route	**Beginning Milepost**	**Ending Milepost**	**PSC**	**PSR**	**Year Due: WSPMS**	**Predicted Year: Base**	**Predicted Year: Impact**	**Difference in Present Value of Cost**
27	1.52	1.61	89	4.2	2007	2007	2006	$952
27	2.18	2.99	77	3.8	2003	2007	2004	$18,483
27	3.70	8.74	84	4.0	2006	2006	2005	$38,313
27	8.74	8.87	100	4.5	2014	2014	2012	$1,439
28	117.28	117.29	53	3.1	2003	2015	2011	$222
28	117.29	117.64	53	3.1	2003	2015	2011	$7,753
28	117.64	117.70	61	3.3	2003	2015	2011	$1,329
28	130.68	130.79	77	3.8	2005	2006	2004	$1,709
28	130.79	131.18	85	4.1	2007	2007	2006	$2,842
90	226.05	226.32	100	4.5	2011	2011	2010	$3,225
124	17.61	17.67	100	4.5	2010	2010	2009	$385
124	18.93	20.12	86	4.1	2006	2006	2005	$9,046
124	20.12	21.94	100	4.5	2010	2010	2009	$11,677
124	21.94	22.62	100	4.5	2010	2010	2009	$4,363
124	22.62	22.65	100	4.5	2010	2010	2009	$192
124	22.65	22.73	100	4.5	2010	2010	2009	$513
124	31.00	35.02	98	4.4	2008	2008	2007	$28,075
124	36.01	36.50	95	4.4	2007	2007	2006	$3,570
124	41.32	41.40	92	4.3	2006	2017	2015	$780
124	41.40	44.20	88	4.1	2005	2006	2005	$21,285
124	44.20	44.22	99	4.5	2009	2009	2008	$134
124	44.22	44.50	99	4.5	2009	2009	2008	$1,874
127	11.03	11.23	62	3.4	2003	2003	2002	$1,727
127	11.03	11.23	62	3.4	2003	2003	2002	$1,727
127	19.93	20.16	75	3.8	2004	2011	2006	$7,712
127	19.93	20.16	75	3.8	2004	2011	2003	$13,188
127	21.64	22.14	70	3.6	2003	2012	2006	$19,712
127	21.64	22.14	70	3.6	2003	2012	2003	$31,616
127	22.51	22.71	79	3.9	2005	2005	2003	$3,241
127	22.51	22.71	79	3.9	2005	2005	2002	$4,968
127	22.71	22.99	83	4.0	2005	2012	2006	$11,039
127	22.71	22.99	83	4.0	2005	2012	2003	$17,705
127	22.99	23.18	79	3.9	2005	2005	2003	$3,079
127	22.99	23.18	79	3.9	2005	2005	2002	$4,719
127	23.18	23.33	80	3.9	2004	2004	2002	$2,536
127	23.18	23.33	80	3.9	2004	2004	2002	$2,536
127	23.33	23.81	83	4.0	2005	2011	2006	$16,095
127	23.33	23.81	83	4.0	2005	2011	2003	$27,522
127	25.39	25.57	78	3.8	2005	2005	2003	$2,917
127	25.39	25.57	78	3.8	2005	2005	2002	$4,471
127	25.74	26.95	86	4.1	2005	2016	2010	$40,264

Table 1. Estimated Build-Sooner Cost for Asphalt-Concrete Pavements Impacted by Potential Abandonment								
Route	Beginning Milepost	Ending Milepost	PSC	PSR	Year Due: WSPMS	Predicted Year: Base	Predicted Year: Impact	Difference in Present Value of Cost
127	25.74	26.95	86	4.1	2005	2016	2006	$73,394
195	36.91	37.02	100	4.5	2010	2010	2009	$706
195	41.93	43.44	100	4.5	2009	2013	2012	$8,532
195	41.93	43.44	100	4.5	2009	2013	2011	$17,432
195	44.02	44.24	100	4.5	2009	2014	2013	$1,191
195	44.24	44.25	100	4.5	2009	2015	2014	$52
195	44.24	44.25	100	4.5	2009	2015	2013	$106
195	44.25	44.40	100	4.5	2009	2015	2014	$779
195	44.25	44.40	100	4.5	2009	2015	2013	$1,591
195	62.15	62.30	92	4.3	2007	2011	2010	$922
195	62.30	62.36	92	4.3	2007	2011	2010	$369
195	63.31	63.34	92	4.3	2007	2009	2008	$201
270	2.48	2.60	84	4.0	2006	2006	2005	$1,324
270	3.13	3.25	100	4.5	2010	2010	2009	$1,895
395	22.96	23.09	100	4.5	2009	2009	2008	$2,142
395	23.51	23.63	100	4.5	2009	2014	2013	$1,600
								$1,090,452

Past-due cost for individual highway segments

Table 2 shows the estimated years past due and the past-due costs for individual highway segments. The number of years past due was derived from the estimated difference in remaining service life, with and without the incremental truck traffic. The additional costs associated with past due projects reflect the typical increase in paving cost shown in Table 8 of the main report.

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	Beginning Milepost	Ending Milepost	Years Past Due	Present Value of Future Cost
2	214.41	214.76	> 6	$64,746
2	214.76	214.86	> 6	$16,995
2	214.86	214.88	> 6	$3,258
2	214.88	215.06	> 6	$29,322
2	215.06	220.88	> 6	$908,729
2	220.88	221.19	3 to 6	$22,234
2	221.54	221.62	3 to 6	$5,986
2	221.62	221.89	3 to 6	$21,079
2	221.89	221.95	> 6	$9,774
2	221.95	221.96	> 6	$1,629

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	**Beginning Milepost**	**Ending Milepost**	**Years Past Due**	**Present Value of Future Cost**
2	221.96	222.05	> 6	$14,661
2	222.05	222.48	> 6	$70,047
2	222.48	223.85	< 3	$53,478
2	223.85	224.00	> 6	$22,449
2	224.00	224.15	> 6	$23,421
2	224.15	224.80	> 6	$93,241
2	224.80	224.90	> 6	$13,749
2	224.90	226.70	> 6	$258,205
2	226.70	228.10	> 6	$200,826
2	228.10	229.48	> 6	$197,957
2	229.48	230.07	> 6	$84,634
2	230.07	230.15	> 6	$12,491
2	230.15	230.47	3 to 6	$24,982
2	261.09	263.27	< 3	$78,179
2	263.27	263.45	3 to 6	$11,861
2	263.45	263.72	3 to 6	$17,791
2	263.72	263.77	3 to 6	$3,586
2	263.77	263.97	3 to 6	$14,345
12	304.51	304.81	< 3	$12,746
12	305.16	305.88	< 3	$30,592
12	306.76	306.79	< 3	$1,275
12	306.79	306.90	< 3	$4,674
12	311.36	311.37	< 3	$390
12	311.37	313.97	< 3	$101,490
12	313.97	314.01	< 3	$1,434
12	314.01	314.16	< 3	$5,379
12	314.16	314.20	< 3	$1,434
12	314.20	314.27	< 3	$2,510
12	315.37	315.89	< 3	$18,648
12	315.89	316.07	< 3	$6,455
12	319.67	319.83	< 3	$5,738
12	319.83	320.09	< 3	$8,566
12	320.09	322.88	< 3	$91,922
12	323.06	323.07	< 3	$329
12	323.07	324.12	< 3	$34,594
12	324.42	324.61	< 3	$6,260
12	324.61	324.74	< 3	$4,283
12	325.98	326.27	< 3	$9,158
12	326.27	326.44	< 3	$5,369
12	326.44	328.75	< 3	$72,949
12	328.75	328.86	< 3	$3,474
12	328.86	328.95	< 3	$2,842
12	328.95	329.03	< 3	$2,526

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	Beginning Milepost	Ending Milepost	Years Past Due	Present Value of Future Cost
12	335.90	335.94	< 3	$1,769
12	335.94	336.00	< 3	$2,653
12	357.59	357.68	3 to 6	$8,325
12	357.68	357.71	< 3	$1,076
12	357.71	357.86	< 3	$5,379
12	357.86	358.70	3 to 6	$53,054
12	358.70	359.04	3 to 6	$21,474
12	359.04	359.35	3 to 6	$19,579
12	359.35	359.55	3 to 6	$12,632
12	359.55	360.28	3 to 6	$46,106
12	360.28	360.29	3 to 6	$632
12	360.29	361.49	3 to 6	$75,791
12	361.49	361.51	3 to 6	$1,263
12	361.51	361.56	3 to 6	$3,158
12	361.56	362.87	3 to 6	$82,738
12	362.87	363.95	3 to 6	$68,212
12	363.95	364.06	< 3	$3,945
12	364.06	364.07	< 3	$359
12	364.07	364.23	< 3	$5,738
12	364.45	366.10	3 to 6	$104,212
12	366.30	366.42	< 3	$4,303
12	366.42	366.51	< 3	$3,228
12	366.90	366.99	3 to 6	$5,537
12	367.41	367.55	3 to 6	$8,842
12	367.55	367.59	< 3	$1,434
17	7.48	7.59	< 3	$3,781
17	7.59	7.67	< 3	$2,869
17	7.67	7.73	< 3	$2,245
17	7.73	8.28	< 3	$23,369
17	8.28	8.71	< 3	$17,512
17	8.71	8.74	< 3	$1,387
17	8.74	8.82	< 3	$3,700
17	8.82	9.09	< 3	$12,487
17	9.09	9.21	< 3	$4,684
17	9.21	9.39	< 3	$7,026
17	9.39	10.00	< 3	$25,918
17	10.32	11.10	< 3	$33,141
17	11.10	12.73	< 3	$72,255
17	12.73	12.80	< 3	$2,851
17	12.80	19.07	3 to 6	$449,708
17	19.07	19.08	3 to 6	$717
17	19.08	20.02	3 to 6	$67,420
17	20.02	21.35	3 to 6	$95,393

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	Beginning Milepost	Ending Milepost	Years Past Due	Present Value of Future Cost
17	21.35	21.80	3 to 6	$32,276
17	21.80	22.03	3 to 6	$15,812
17	22.03	22.19	> 6	$21,999
17	22.19	23.20	> 6	$138,869
17	23.20	25.35	3 to 6	$147,806
17	25.35	26.09	3 to 6	$50,873
17	26.09	27.67	< 3	$54,310
17	27.67	27.81	< 3	$4,613
17	27.81	27.94	< 3	$4,283
17	28.66	29.01	3 to 6	$23,063
17	29.01	32.45	< 3	$118,245
17	33.07	33.43	< 3	$12,374
17	34.24	34.30	< 3	$2,062
17	34.30	34.44	< 3	$4,812
17	39.74	39.86	< 3	$4,125
17	39.86	40.24	< 3	$13,062
17	48.28	48.64	< 3	$12,374
17	53.91	54.24	< 3	$15,774
17	54.58	54.89	< 3	$14,818
17	54.89	54.99	< 3	$4,063
17	55.86	56.25	< 3	$12,516
17	91.60	92.22	< 3	$25,249
17	92.22	92.56	< 3	$15,072
17	94.45	94.57	< 3	$5,099
17	94.57	94.83	< 3	$11,525
17	94.83	95.06	< 3	$10,637
17	95.06	95.99	3 to 6	$75,748
17	95.99	96.57	< 3	$23,620
21	24.50	24.74	> 6	$30,316
21	26.49	26.60	3 to 6	$8,959
21	26.60	26.75	3 to 6	$12,746
21	55.83	55.90	3 to 6	$5,948
21	55.90	55.96	3 to 6	$5,099
21	55.96	56.03	3 to 6	$5,948
21	56.03	56.15	3 to 6	$10,639
21	56.15	56.27	3 to 6	$10,197
21	56.27	56.36	3 to 6	$7,026
21	91.35	91.72	< 3	$13,269
21	91.72	91.73	< 3	$329
21	91.73	91.78	< 3	$1,647
23	14.02	14.23	3 to 6	$19,424
23	14.23	14.36	3 to 6	$11,525
23	14.36	14.41	3 to 6	$4,625

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	**Beginning Milepost**	**Ending Milepost**	**Years Past Due**	**Present Value of Future Cost**
26	116.74	116.92	3 to 6	$13,469
26	116.92	117.20	3 to 6	$20,083
26	116.92	117.20	3 to 6	$20,083
26	117.20	117.22	< 3	$717
26	117.20	117.22	< 3	$717
26	117.22	117.89	< 3	$24,027
26	117.22	117.89	< 3	$24,027
26	117.89	118.10	< 3	$7,531
26	117.89	118.10	< 3	$7,531
26	118.10	119.09	< 3	$35,503
26	118.10	119.09	< 3	$35,503
26	119.09	119.14	< 3	$1,793
26	119.09	119.14	< 3	$1,793
26	119.14	119.16	< 3	$717
26	119.14	119.16	< 3	$717
26	119.16	123.27	< 3	$147,392
26	119.16	123.27	< 3	$147,392
26	123.27	123.69	< 3	$15,062
26	123.69	124.01	< 3	$11,476
26	123.69	124.01	< 3	$11,476
26	124.01	124.88	< 3	$31,200
26	124.88	124.94	< 3	$2,152
26	124.88	124.94	< 3	$2,152
26	124.94	124.99	< 3	$1,793
26	124.94	124.99	< 3	$1,793
26	124.99	125.16	< 3	$6,097
26	124.99	125.16	< 3	$6,097
26	125.16	125.26	< 3	$3,741
26	125.16	125.26	3 to 6	$7,483
26	125.26	125.27	< 3	$390
26	125.26	125.27	< 3	$390
26	125.27	125.89	< 3	$24,202
26	125.27	125.89	< 3	$24,202
26	125.89	125.90	< 3	$359
26	125.89	125.90	< 3	$359
26	125.90	126.05	< 3	$5,379
26	125.90	126.05	< 3	$5,379
26	126.05	126.06	< 3	$359
26	126.05	126.06	< 3	$359
26	126.06	126.33	< 3	$9,683
26	126.06	126.33	< 3	$9,683
26	126.33	126.41	< 3	$2,869
26	126.33	126.41	< 3	$2,869

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	**Beginning Milepost**	**Ending Milepost**	**Years Past Due**	**Present Value of Future Cost**
26	126.41	128.08	< 3	$59,889
26	126.41	128.08	< 3	$59,889
26	128.08	129.56	< 3	$53,076
26	128.08	129.56	< 3	$53,076
26	131.88	132.00	3 to 6	$8,607
26	131.88	132.00	3 to 6	$8,607
26	132.28	132.94	< 3	$23,669
26	132.28	132.94	< 3	$23,669
26	132.94	133.06	> 6	$15,158
26	133.06	133.30	> 6	$30,316
26	133.44	133.47	> 6	$3,790
26	133.47	133.50	> 6	$3,790
26	133.50	133.51	> 6	$1,263
27	0.00	0.11	3 to 6	$10,516
27	0.11	0.24	< 3	$7,056
27	0.85	1.39	3 to 6	$53,858
27	1.39	1.45	< 3	$2,868
27	1.45	1.52	< 3	$3,491
27	1.52	1.61	< 3	$5,097
27	2.18	2.99	3 to 6	$74,921
27	3.70	8.74	< 3	$205,254
28	103.12	103.57	> 6	$61,872
28	103.57	104.47	> 6	$129,103
28	104.47	105.32	> 6	$112,019
28	105.32	117.28	> 6	$1,644,428
28	117.28	117.29	3 to 6	$925
28	117.29	117.64	3 to 6	$32,373
28	117.64	117.70	3 to 6	$5,550
28	130.68	130.79	< 3	$4,674
28	130.79	131.18	< 3	$15,224
90	226.05	226.32	< 3	$8,665
124	17.61	17.67	< 3	$2,062
124	18.93	20.12	< 3	$48,463
124	20.12	21.94	< 3	$62,560
124	21.94	22.62	< 3	$23,374
124	22.62	22.65	< 3	$1,031
124	22.65	22.73	< 3	$2,750
124	31.00	35.02	< 3	$150,407
124	36.01	36.50	< 3	$19,127
124	41.32	41.40	< 3	$3,258
124	41.40	44.20	< 3	$118,967
124	44.20	44.22	< 3	$717
124	44.22	44.50	< 3	$10,041

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	**Beginning Milepost**	**Ending Milepost**	**Years Past Due**	**Present Value of Future Cost**
127	11.03	11.23	< 3	$9,249
127	11.03	11.23	3 to 6	$18,499
127	19.93	20.16	3 to 6	$20,391
127	19.93	20.16	> 6	$40,782
127	21.64	22.14	3 to 6	$46,247
127	21.64	22.14	> 6	$92,495
127	22.51	22.71	< 3	$8,498
127	22.51	22.71	3 to 6	$16,995
127	22.71	22.99	3 to 6	$23,793
127	22.71	22.99	> 6	$47,587
127	22.99	23.18	< 3	$8,073
127	22.99	23.18	3 to 6	$16,146
127	23.18	23.33	< 3	$6,649
127	23.18	23.33	3 to 6	$13,298
127	23.33	23.81	3 to 6	$40,789
127	23.33	23.81	> 6	$81,578
127	24.00	25.39	> 6	$236,235
127	24.00	25.39	> 6	$236,235
127	25.39	25.57	< 3	$7,648
127	25.39	25.57	3 to 6	$15,296
127	25.74	26.95	3 to 6	$102,822
127	25.74	26.95	> 6	$205,644
195	19.79	19.96	> 6	$24,386
195	19.96	20.19	> 6	$32,993
195	20.19	20.28	> 6	$12,910
195	20.28	20.81	3 to 6	$38,014
195	20.81	22.89	< 3	$74,593
195	22.39	22.89	< 3	$17,931
195	26.80	27.09	< 3	$9,555
195	26.80	27.09	< 3	$9,555
195	27.09	27.48	< 3	$12,849
195	27.09	27.48	< 3	$12,849
195	27.48	28.75	3 to 6	$83,685
195	27.48	28.75	< 3	$41,843
195	28.75	29.14	< 3	$12,849
195	28.75	29.14	< 3	$12,849
195	29.14	30.55	< 3	$44,527
195	29.14	30.55	< 3	$44,527
195	30.55	30.94	3 to 6	$24,632
195	30.55	30.94	< 3	$12,316
195	30.94	33.97	3 to 6	$191,372
195	30.94	33.97	3 to 6	$191,372
195	33.97	34.20	3 to 6	$14,527

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	Beginning Milepost	Ending Milepost	Years Past Due	Present Value of Future Cost
195	33.97	34.20	3 to 6	$14,527
195	34.20	34.27	3 to 6	$4,421
195	34.20	34.27	3 to 6	$4,421
195	34.27	34.38	< 3	$3,474
195	34.27	34.38	< 3	$3,474
195	36.91	37.02	< 3	$3,781
195	37.21	37.26	< 3	$1,647
195	37.21	37.26	3 to 6	$3,295
195	37.26	37.32	< 3	$1,977
195	37.26	37.32	3 to 6	$3,954
195	37.32	37.46	< 3	$4,613
195	37.32	37.46	3 to 6	$9,225
195	37.46	37.47	< 3	$329
195	37.46	37.47	3 to 6	$659
195	37.47	37.49	< 3	$659
195	37.47	37.49	3 to 6	$1,318
195	37.49	37.55	< 3	$1,926
195	37.49	37.55	< 3	$1,926
195	37.55	37.57	< 3	$699
195	37.55	37.57	< 3	$699
195	37.57	38.09	< 3	$18,165
195	37.57	38.09	< 3	$18,165
195	37.81	38.09	< 3	$9,781
195	38.09	38.14	< 3	$1,747
195	38.09	38.14	< 3	$1,747
195	38.14	38.28	< 3	$4,891
195	38.14	38.28	< 3	$4,891
195	38.28	38.30	< 3	$699
195	38.28	38.30	< 3	$699
195	38.30	38.38	< 3	$2,795
195	38.30	38.38	< 3	$2,795
195	38.38	38.46	< 3	$2,567
195	38.38	38.46	< 3	$2,567
195	38.46	38.50	< 3	$1,318
195	38.46	38.50	< 3	$1,318
195	38.50	38.55	3 to 6	$3,158
195	38.50	38.55	3 to 6	$3,158
195	38.55	38.58	3 to 6	$1,895
195	38.55	38.58	< 3	$947
195	38.55	38.61	3 to 6	$3,790
195	38.58	38.61	< 3	$947
195	38.58	38.61	3 to 6	$1,895
195	38.61	39.00	3 to 6	$24,632

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	**Beginning Milepost**	**Ending Milepost**	**Years Past Due**	**Present Value of Future Cost**
195	38.61	39.00	3 to 6	$24,632
195	39.83	40.04	< 3	$7,531
195	39.83	40.04	3 to 6	$15,062
195	40.04	40.20	< 3	$5,738
195	40.04	40.20	3 to 6	$11,476
195	40.20	40.36	< 3	$5,738
195	40.20	40.36	3 to 6	$11,476
195	40.36	40.51	3 to 6	$9,474
195	40.36	40.51	> 6	$18,948
195	40.51	41.82	< 3	$46,979
195	40.51	41.82	< 3	$46,979
195	41.82	41.93	< 3	$3,945
195	41.82	41.93	< 3	$3,945
195	41.93	43.44	< 3	$54,151
195	41.93	43.44	< 3	$54,151
195	43.44	43.57	< 3	$4,662
195	43.44	43.57	< 3	$4,662
195	43.57	43.81	< 3	$8,607
195	43.57	43.81	< 3	$8,607
195	43.81	44.02	< 3	$7,531
195	43.81	44.02	< 3	$7,531
195	44.02	44.24	< 3	$7,890
195	44.24	44.25	< 3	$359
195	44.24	44.25	< 3	$359
195	44.25	44.40	< 3	$5,379
195	44.25	44.40	< 3	$5,379
195	62.15	62.30	< 3	$5,855
195	62.30	62.36	< 3	$2,342
195	63.31	63.34	< 3	$1,171
195	63.34	65.57	< 3	$87,047
195	65.57	65.68	< 3	$4,116
195	65.68	65.97	< 3	$10,850
195	65.97	66.04	< 3	$2,510
195	66.04	66.11	< 3	$2,510
195	66.11	66.19	< 3	$3,123
195	66.19	67.14	< 3	$37,083
195	67.14	67.17	< 3	$1,171
195	67.17	69.94	< 3	$108,126
195	69.94	70.65	< 3	$24,405
195	69.94	70.78	< 3	$28,874
195	70.78	70.81	< 3	$1,031
195	70.81	71.63	< 3	$28,186
195	71.63	71.67	< 3	$1,375

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	**Beginning Milepost**	**Ending Milepost**	**Years Past Due**	**Present Value of Future Cost**
195	71.67	73.53	< 3	$63,935
195	73.53	73.55	< 3	$687
195	73.55	75.41	< 3	$63,935
195	75.41	75.43	< 3	$687
195	75.43	76.55	< 3	$38,498
195	76.55	76.58	< 3	$1,031
195	76.58	78.40	< 3	$62,560
195	78.88	78.93	< 3	$1,719
231	15.62	15.76	> 6	$20,083
231	15.76	15.98	> 6	$28,993
231	15.98	15.99	> 6	$1,434
231	15.99	16.05	> 6	$8,607
231	16.05	16.12	> 6	$10,041
231	16.12	16.20	> 6	$11,476
231	16.20	16.30	> 6	$14,345
231	26.20	28.11	> 6	$285,848
270	0.06	0.12	> 6	$9,368
270	0.06	0.12	> 6	$9,368
270	0.12	0.70	> 6	$90,561
270	0.12	0.70	> 6	$90,561
270	0.70	0.75	> 6	$13,419
270	0.70	0.75	> 6	$13,419
270	0.75	1.57	3 to 6	$105,469
270	0.75	1.57	3 to 6	$105,469
270	1.57	2.19	3 to 6	$83,198
270	1.57	2.19	< 3	$41,599
270	2.48	2.60	< 3	$7,090
270	2.67	2.84	< 3	$8,537
270	2.84	2.96	3 to 6	$11,073
270	2.96	2.98	3 to 6	$1,558
270	2.98	3.13	3 to 6	$11,683
270	3.13	3.25	< 3	$5,087
270	4.10	5.33	3 to 6	$122,676
270	5.33	5.63	> 6	$59,842
270	5.63	5.75	> 6	$16,499
270	5.75	8.11	> 6	$324,486
270	8.11	9.26	> 6	$158,118
395	22.72	22.78	3 to 6	$5,307
395	22.78	22.96	3 to 6	$15,920
395	22.96	23.09	< 3	$5,749
395	23.51	23.63	< 3	$5,307
395	36.14	37.10	> 6	$134,142
395	37.23	37.37	3 to 6	$9,781

Table 2. Estimates of Past-Due Preservation Resurfacing Costs as a Result of Potential PCC System Abandonment				
Route	Beginning Milepost	Ending Milepost	Years Past Due	Present Value of Future Cost
395	37.37	37.51	3 to 6	$9,781
395	37.51	37.75	> 6	$33,535
395	39.68	43.50	> 6	$533,773
Total Past Due Cost				$14,730,710

Incremental thickness cost for individual highway segments

Table 3 shows the estimated incremental thickness and pavement cost for most of the potentially-impacted routes. Because of the size of the table, interstate and principal arterial routes are not shown. For each segment included in the table, the projected incremental truck trips per year and the percent increase in ESALs are shown, as well as the incremental overlay thickness and resulting cost.

Table 3. Estimated Incremental Overlay Thickness and Pavement Costs Resulting from Potential PCC Abandonment									
Route	Begin MP	End MP	Miles	SN	Annual Additional Trucks	Percent Increase in ESALs	Incremental Inches of Overlay	Incremental Pavement Cost	Present Value of Cost
2	210.55	210.57	0.02	4.2	4,112	51	0.82	$1,750	$1,750
2	210.57	213.56	2.99	4.2	4,112	51	0.82	$261,585	$261,585
2	213.56	214.41	0.85	5.9	4,112	46	0.88	$80,666	$74,109
2	214.41	214.76	0.35	3.6	4,112	52	0.71	$26,518	$25,418
2	214.76	214.86	0.10	3.3	4,112	52	0.65	$6,979	$6,146
2	214.86	214.88	0.02	3.3	4,112	52	0.65	$1,396	$1,178
2	214.88	215.06	0.18	3.3	4,112	52	0.65	$12,562	$10,603
2	215.06	220.88	5.82	3.4	4,112	50	0.65	$403,344	$326,309
2	220.88	221.19	0.31	4.0	4,112	22	0.33	$11,027	$8,196
2	221.19	221.34	0.15	6.0	4,112	18	0.34	$5,490	$4,081
2	221.34	221.42	0.08	6.0	4,112	17	0.32	$2,760	$2,140
2	221.42	221.48	0.06	6.0	4,112	16	0.31	$2,021	$1,567
2	221.48	221.54	0.06	6.0	4,112	16	0.31	$1,968	$1,526
2	221.54	221.62	0.08	6.0	611	3	0.05	$423	$328
2	221.62	221.89	0.27	6.0	611	3	0.05	$1,549	$1,253
2	221.89	221.95	0.06	6.0	611	3	0.06	$375	$317
2	221.95	221.96	0.01	6.0	611	3	0.06	$65	$55
2	221.96	222.05	0.09	6.0	611	3	0.06	$586	$495
2	222.05	222.48	0.43	6.0	611	3	0.07	$3,117	$2,631
2	222.48	223.85	1.37	4.1	611	4	0.06	$9,045	$7,318
2	223.85	224.00	0.15	5.9	611	4	0.07	$1,113	$863
2	224.00	224.15	0.15	6.0	611	4	0.07	$1,131	$915
2	224.15	224.80	0.65	5.7	611	4	0.07	$4,764	$3,541
2	224.80	224.90	0.10	5.7	611	4	0.07	$734	$523
2	224.90	226.70	1.80	5.7	611	4	0.07	$13,364	$9,933

Table 3. Estimated Incremental Overlay Thickness and Pavement Costs Resulting from Potential PCC Abandonment									
Route	**Begin MP**	**End MP**	**Miles**	**SN**	**Annual Additional Trucks**	**Percent Increase in ESALs**	**Incremental Inches of Overlay**	**Incremental Pavement Cost**	**Present Value of Cost**
2	226.70	228.10	1.40	5.7	611	4	0.07	$10,284	$7,644
2	228.10	229.48	1.38	5.7	611	4	0.07	$10,007	$7,438
2	229.48	230.07	0.59	5.7	611	4	0.07	$4,240	$3,151
2	230.07	230.15	0.08	5.7	611	4	0.07	$573	$463
2	230.15	230.47	0.32	5.7	611	3	0.06	$2,114	$1,710
2	261.09	263.27	2.18	4.3	1,084	4	0.06	$14,395	$10,699
2	263.27	263.45	0.18	6.0	1,084	3	0.06	$1,101	$752
2	263.45	263.72	0.27	6.0	1,084	3	0.06	$1,612	$1,101
2	263.72	263.77	0.05	6.0	1,084	3	0.06	$295	$219
2	263.77	263.97	0.20	6.0	1,084	3	0.05	$1,166	$866
17	7.48	7.59	0.11	5.2	3,286	4	0.07	$873	$622
17	7.59	7.67	0.08	5.2	3,286	4	0.07	$620	$461
17	7.67	7.73	0.06	5.2	3,286	4	0.07	$471	$365
17	7.73	8.28	0.55	5.2	3,286	5	0.08	$4,559	$4,015
17	8.28	8.71	0.43	5.2	3,286	5	0.08	$3,619	$3,055
17	8.71	8.74	0.03	5.2	3,286	5	0.08	$244	$234
17	8.74	8.82	0.08	5.2	3,286	5	0.08	$650	$623
17	8.82	9.09	0.27	5.2	3,286	4	0.07	$2,145	$2,056
17	9.09	9.21	0.12	5.2	3,286	4	0.07	$921	$745
17	9.21	9.39	0.18	5.2	3,286	4	0.07	$1,381	$1,117
17	9.39	10.00	0.61	5.2	3,286	4	0.07	$4,489	$3,953
17	10.00	10.32	0.32	5.2	3,286	4	0.07	$2,291	$1,853
17	10.32	11.10	0.78	5.2	3,286	4	0.07	$5,763	$5,075
17	11.10	12.73	1.63	5.2	3,286	4	0.07	$12,957	$11,903
17	12.73	12.80	0.07	5.2	3,286	5	0.08	$587	$496
17	12.80	19.07	6.27	6.0	3,286	5	0.10	$65,898	$48,979
17	19.07	19.08	0.01	6.0	3,286	5	0.10	$107	$80
17	19.08	20.02	0.94	6.0	3,286	5	0.10	$10,088	$7,498
17	20.02	21.35	1.33	6.0	3,286	5	0.10	$14,273	$10,608
17	21.35	21.80	0.45	6.0	3,286	5	0.10	$4,829	$3,589
17	21.80	22.03	0.23	5.1	3,286	8	0.13	$3,133	$2,232
17	22.03	22.19	0.16	5.1	3,286	16	0.26	$4,506	$3,210
17	22.19	23.20	1.01	5.1	3,286	16	0.27	$28,891	$20,582
17	23.20	25.35	2.15	5.1	3,286	11	0.18	$40,481	$28,839
17	25.35	26.09	0.74	5.1	3,286	8	0.13	$10,632	$7,574
17	26.09	27.67	1.58	5.1	3,286	7	0.11	$19,140	$13,636
17	27.67	27.81	0.14	5.1	3,286	6	0.11	$1,586	$1,083
17	27.81	27.94	0.13	5.1	3,286	6	0.11	$1,473	$1,006
17	27.94	28.38	0.44	5.5	3,286	6	0.11	$5,268	$3,597
17	28.38	28.66	0.28	5.5	3,286	6	0.11	$3,284	$2,242
17	28.66	29.01	0.35	5.5	3,286	6	0.11	$4,161	$2,841
17	29.01	32.45	3.44	5.5	3,286	6	0.10	$37,340	$26,601
17	32.45	33.07	0.62	4.0	3,286	6	0.09	$5,857	$4,173
17	33.07	33.43	0.36	3.6	3,286	6	0.08	$3,100	$2,209
17	33.43	33.44	0.01	4.0	3,286	6	0.09	$94	$67

Table 3. Estimated Incremental Overlay Thickness and Pavement Costs Resulting from Potential PCC Abandonment									
Route	**Begin MP**	**End MP**	**Miles**	**SN**	**Annual Additional Trucks**	**Percent Increase in ESALs**	**Incremental Inches of Overlay**	**Incremental Pavement Cost**	**Present Value of Cost**
17	33.44	34.10	0.66	4.0	3,286	6	0.09	$6,175	$4,399
17	34.10	34.24	0.14	3.1	3,286	6	0.07	$1,030	$734
17	34.24	34.30	0.06	3.6	3,286	6	0.08	$511	$364
17	34.30	34.44	0.14	5.1	3,286	5	0.09	$1,323	$942
17	34.44	35.50	1.06	3.9	3,286	6	0.08	$9,576	$6,822
17	35.50	35.60	0.10	3.9	3,286	5	0.08	$866	$617
17	35.60	36.03	0.43	3.9	3,286	5	0.07	$3,250	$2,315
17	36.03	36.83	0.80	3.9	3,286	5	0.07	$5,970	$4,253
17	36.83	36.95	0.12	3.9	3,286	5	0.07	$887	$632
17	36.95	37.47	0.52	3.9	3,286	5	0.07	$3,811	$2,715
17	37.47	37.86	0.39	3.9	3,286	5	0.07	$2,835	$2,019
17	37.86	38.29	0.43	3.2	3,286	5	0.06	$2,585	$1,841
17	38.29	39.32	1.03	4.1	3,286	4	0.07	$7,618	$5,427
17	39.32	39.74	0.42	3.7	3,286	4	0.06	$2,817	$2,007
17	39.74	39.86	0.12	4.1	3,286	5	0.07	$930	$662
17	39.86	40.24	0.38	3.2	3,286	5	0.06	$2,415	$1,720
17	40.24	41.31	1.07	3.7	3,286	5	0.07	$7,771	$5,536
17	41.31	42.19	0.88	3.7	3,286	5	0.07	$6,181	$4,404
17	42.19	42.66	0.47	2.3	3,286	5	0.04	$2,137	$1,523
17	42.66	42.83	0.17	2.3	3,286	5	0.04	$791	$563
17	42.83	42.87	0.04	2.3	3,286	5	0.04	$188	$134
17	42.87	43.00	0.13	3.8	3,286	5	0.07	$991	$706
17	43.00	45.22	2.22	3.4	3,286	5	0.07	$16,740	$11,925
17	45.22	45.90	0.68	3.1	3,286	6	0.07	$5,442	$3,877
17	45.90	47.91	2.01	3.1	3,286	7	0.08	$16,548	$11,789
17	47.91	48.09	0.18	3.1	3,286	6	0.07	$1,371	$977
17	48.09	48.10	0.01	3.1	3,286	6	0.07	$74	$53
17	48.10	48.28	0.18	3.1	3,286	6	0.07	$1,339	$954
17	48.28	48.64	0.36	3.1	3,286	6	0.07	$2,591	$1,846
17	48.64	49.03	0.39	2.0	3,286	5	0.04	$1,733	$1,234
17	49.03	49.71	0.68	2.4	3,286	5	0.05	$3,769	$2,685
17	49.71	50.22	0.51	3.0	3,286	6	0.07	$3,754	$2,675
17	50.22	50.40	0.18	2.5	3,286	5	0.06	$1,071	$763
17	50.40	50.53	0.13	3.2	3,286	6	0.07	$959	$655
17	50.53	50.67	0.14	3.8	3,286	5	0.07	$1,585	$1,082
17	50.67	50.74	0.07	3.8	3,286	4	0.06	$685	$468
17	50.74	50.77	0.03	3.7	3,286	4	0.06	$287	$196
17	50.77	50.86	0.09	3.7	3,286	4	0.06	$861	$588
17	50.86	51.03	0.17	3.7	3,286	4	0.06	$1,243	$848
17	51.03	51.75	0.72	3.0	3,286	6	0.08	$7,230	$4,937
17	51.75	51.93	0.18	3.0	3,286	7	0.08	$997	$681
17	51.93	51.98	0.05	3.0	3,286	9	0.11	$862	$588
17	51.98	53.09	1.11	3.6	3,286	8	0.11	$19,020	$12,988
17	53.09	53.22	0.13	3.2	3,286	8	0.10	$2,000	$1,366
17	53.22	53.34	0.12	3.2	3,286	8	0.10	$1,809	$1,235

Table 3. Estimated Incremental Overlay Thickness and Pavement Costs Resulting from Potential PCC Abandonment									
Route	Begin MP	End MP	Miles	SN	Annual Additional Trucks	Percent Increase in ESALs	Incremental Inches of Overlay	Incremental Pavement Cost	Present Value of Cost
17	53.34	53.80	0.46	3.6	3,286	8	0.11	$7,766	$5,303
17	53.80	53.91	0.11	3.3	3,286	8	0.10	$1,711	$1,168
17	53.91	54.24	0.33	3.3	3,286	7	0.08	$4,192	$2,863
17	54.24	54.26	0.02	3.3	3,286	7	0.08	$263	$180
17	54.26	54.42	0.16	3.3	3,286	7	0.08	$2,103	$1,436
17	54.42	54.58	0.16	3.3	3,286	8	0.10	$2,493	$1,702
17	54.58	54.89	0.31	3.3	3,286	11	0.13	$6,428	$4,389
17	54.89	54.99	0.10	3.1	3,286	11	0.13	$880	$601
17	54.99	55.32	0.33	3.1	3,286	5	0.05	$2,335	$1,595
17	55.86	56.25	0.39	3.1	3,286	8	0.09	$3,754	$2,563
17	56.25	56.57	0.32	2.6	3,286	8	0.08	$2,713	$1,852
17	91.60	92.22	0.62	2.2	3,286	29	0.25	$16,852	$14,224
17	92.22	92.56	0.34	2.2	3,286	26	0.23	$8,306	$7,630
17	92.56	92.75	0.19	2.2	3,286	25	0.22	$4,482	$2,934
17	92.75	93.22	0.47	2.2	3,286	25	0.22	$11,163	$10,700
17	93.22	94.45	1.23	2.2	3,286	25	0.22	$29,214	$28,001
17	94.45	94.57	0.12	2.6	3,286	26	0.27	$3,491	$3,074
17	94.57	94.83	0.26	3.0	3,286	26	0.32	$8,928	$8,202
17	94.83	95.06	0.23	2.7	3,286	26	0.28	$6,999	$6,709
17	95.06	95.99	0.93	3.2	3,286	27	0.32	$32,164	$27,148
17	95.99	96.57	0.58	3.2	3,286	23	0.27	$17,051	$14,392
21	24.45	24.50	0.05	3.4	7,952	110	1.42	$7,630	$4,994
21	24.50	24.74	0.24	3.4	6,868	95	1.23	$31,630	$20,702
21	24.74	24.77	0.03	3.4	6,868	104	1.34	$4,314	$2,823
21	24.77	25.11	0.34	3.4	6,868	104	1.34	$48,887	$31,997
21	26.49	26.60	0.11	2.3	6,868	106	0.99	$11,637	$9,822
21	26.60	26.75	0.15	2.3	6,868	108	1.00	$16,112	$14,188
21	26.75	26.82	0.07	1.9	6,868	105	0.80	$6,025	$5,775
21	26.82	27.00	0.18	1.8	6,868	104	0.75	$14,538	$14,538
21	37.31	37.65	0.34	3.5	6,868	315	4.19	$152,799	$146,458
21	37.65	37.72	0.07	4.0	6,868	335	5.08	$38,150	$35,049
21	37.72	37.78	0.06	3.9	6,868	324	4.80	$30,910	$27,219
21	37.78	37.92	0.14	3.9	6,868	296	4.38	$65,717	$55,468
21	37.92	38.20	0.28	3.9	6,868	264	3.91	$117,341	$103,329
21	55.45	55.57	0.12	1.7	6,868	56	0.39	$4,957	$4,957
21	55.57	55.68	0.11	1.5	6,868	53	0.32	$3,813	$3,813
21	55.68	55.71	0.03	2.3	6,868	56	0.52	$1,682	$1,682
21	55.71	55.83	0.12	2.3	6,868	56	0.52	$6,729	$6,729
21	55.83	55.90	0.07	2.7	6,868	78	0.85	$6,388	$5,626
21	55.90	55.96	0.06	2.7	5,948	68	0.74	$4,742	$4,176
21	55.96	56.03	0.07	2.7	5,948	70	0.77	$5,755	$5,067
21	56.03	56.15	0.12	2.7	5,948	72	0.78	$10,054	$9,236
21	56.15	56.27	0.12	2.7	5,948	75	0.82	$10,510	$9,255
21	56.27	56.36	0.09	2.7	5,948	75	0.82	$7,904	$6,395
21	91.35	91.72	0.37	1.8	5,948	99	0.72	$28,661	$21,302

Table 3. Estimated Incremental Overlay Thickness and Pavement Costs Resulting from Potential PCC Abandonment									
Route	Begin MP	End MP	Miles	SN	Annual Additional Trucks	Percent Increase in ESALs	Incremental Inches of Overlay	Incremental Pavement Cost	Present Value of Cost
21	91.72	91.73	0.01	1.8	5,948	79	0.58	$618	$422
21	91.73	91.78	0.05	1.8	5,948	79	0.58	$3,092	$2,111
23	14.02	14.23	0.21	2.1	3,011	72	0.61	$13,666	$13,099
23	14.23	14.36	0.13	2.4	3,011	73	0.71	$9,846	$9,046
23	14.36	14.41	0.05	2.4	3,011	73	0.71	$3,787	$3,630
26	116.74	116.92	0.18	4.4	1,920	11	0.19	$3,578	$2,774
26	116.92	117.20	0.28	4.1	13,031	45	0.70	$20,957	$15,577
26	117.20	117.22	0.02	3.7	13,031	49	0.69	$1,489	$1,106
26	117.22	117.89	0.67	3.7	13,031	49	0.69	$49,870	$37,066
26	117.89	118.10	0.21	3.3	13,031	54	0.67	$15,154	$11,263
26	118.10	119.09	0.99	3.3	13,031	55	0.69	$73,795	$54,848
26	119.09	119.14	0.05	3.2	13,031	56	0.68	$3,640	$2,705
26	119.14	119.16	0.02	3.0	13,031	56	0.68	$1,461	$1,086
26	119.16	123.27	4.11	3.0	13,031	56	0.68	$300,151	$223,087
26	123.27	123.69	0.42	2.8	13,031	56	0.64	$28,696	$21,329
26	123.69	124.01	0.32	3.4	13,031	57	0.74	$25,360	$18,849
26	124.01	124.88	0.87	2.8	13,031	57	0.64	$59,706	$44,376
26	124.88	124.94	0.06	3.1	13,031	58	0.68	$4,364	$3,243
26	124.94	124.99	0.05	3.1	13,031	58	0.68	$3,636	$2,703
26	124.99	125.16	0.17	3.1	13,031	58	0.68	$12,364	$9,189
26	125.16	125.26	0.10	3.4	13,031	66	0.85	$9,169	$7,110
26	125.26	125.27	0.01	3.1	13,031	64	0.75	$808	$654
26	125.27	125.89	0.62	3.1	13,031	64	0.75	$50,112	$40,541
26	125.89	125.90	0.01	3.1	13,031	63	0.74	$789	$586
26	125.90	126.05	0.15	3.1	13,031	63	0.74	$11,834	$8,796
26	126.05	126.06	0.01	3.1	13,031	61	0.72	$768	$571
26	126.06	126.33	0.27	3.1	13,031	61	0.72	$20,741	$15,416
26	126.33	126.41	0.08	2.8	13,031	60	0.68	$5,800	$4,311
26	126.41	128.08	1.67	3.1	13,031	56	0.66	$118,964	$88,420
26	128.08	128.81	0.73	2.8	226	1	0.01	$611	$454
26	128.08	129.56	1.48	2.8	12,805	49	0.56	$88,644	$65,884
26	129.56	129.57	0.01	2.8	12,805	44	0.50	$535	$398
26	129.57	131.88	2.31	2.8	12,805	44	0.50	$123,605	$91,870
26	131.88	132.00	0.12	4.5	12,805	40	0.68	$8,748	$6,502
26	132.00	132.28	0.28	5.7	12,805	37	0.68	$20,487	$15,227
26	132.28	132.94	0.66	4.1	12,805	34	0.54	$37,954	$28,210
26	132.94	133.06	0.12	6.0	12,805	26	0.50	$6,429	$4,208
26	133.06	133.30	0.24	6.0	12,805	26	0.50	$12,858	$8,415
26	133.30	133.53	0.23	6.0	12,805	32	0.61	$15,090	$9,877
26	133.44	133.47	0.03	5.6	12,805	33	0.59	$1,902	$1,245
26	133.47	133.50	0.03	5.6	12,805	33	0.59	$1,902	$1,245
26	133.50	133.51	0.01	5.6	12,805	33	0.59	$634	$415
127	10.19	10.35	0.16	2.3	14,951	59	0.54	$9,508	$8,735
127	10.35	10.40	0.05	2.3	14,951	53	0.50	$2,664	$2,248
127	10.40	11.03	0.63	2.3	14,951	53	0.50	$33,565	$28,330

Table 3. Estimated Incremental Overlay Thickness and Pavement Costs Resulting from Potential PCC Abandonment									
Route	Begin MP	End MP	Miles	SN	Annual Additional Trucks	Percent Increase in ESALs	Incremental Inches of Overlay	Incremental Pavement Cost	Present Value of Cost
127	11.03	11.23	0.20	3.9	14,951	56	0.83	$17,774	$17,036
127	11.23	11.24	0.01	5.4	14,951	54	0.95	$1,018	$859
127	11.24	13.82	2.58	5.4	14,951	54	0.95	$262,595	$221,641
127	13.82	13.87	0.05	5.4	14,951	57	1.00	$5,352	$4,330
127	13.87	14.02	0.15	5.4	14,951	57	1.00	$16,093	$13,020
127	14.02	14.53	0.51	5.4	14,951	58	1.02	$55,778	$49,117
127	14.53	18.00	3.47	5.4	14,951	63	1.11	$411,839	$362,661
127	18.00	18.13	0.13	5.4	14,951	69	1.20	$16,771	$14,768
127	18.13	18.22	0.09	5.4	14,951	69	1.21	$11,676	$11,676
127	18.22	18.76	0.54	5.4	14,951	70	1.22	$70,701	$70,701
127	18.76	18.88	0.12	5.4	14,951	71	1.24	$15,975	$15,312
127	18.88	18.98	0.10	5.4	14,951	72	1.25	$13,459	$12,901
127	18.98	19.08	0.10	5.4	14,951	72	1.25	$13,459	$13,459
127	19.08	19.18	0.10	5.4	14,951	72	1.26	$13,539	$13,539
127	19.18	19.49	0.31	5.4	14,951	73	1.27	$42,348	$42,348
127	19.49	19.73	0.24	5.4	14,951	75	1.31	$33,692	$33,692
127	19.73	19.93	0.20	5.4	14,951	78	1.35	$29,063	$27,857
127	19.93	20.16	0.23	4.0	14,951	87	1.32	$32,545	$29,900
127	20.16	20.78	0.62	3.3	14,951	94	1.18	$78,384	$78,384
127	20.78	20.98	0.20	3.3	14,951	94	1.18	$25,263	$25,263
127	20.98	21.25	0.27	4.0	14,951	92	1.40	$40,445	$40,445
127	21.25	21.45	0.20	3.3	14,951	94	1.18	$25,263	$25,263
127	21.45	21.64	0.19	3.3	14,951	93	1.16	$23,739	$23,739
127	21.64	22.14	0.50	4.0	14,951	90	1.37	$73,288	$70,246
127	22.14	22.40	0.26	3.3	14,951	92	1.15	$32,136	$32,136
127	22.40	22.41	0.01	3.3	14,951	91	1.14	$1,224	$1,224
127	22.41	22.51	0.10	3.3	14,951	91	1.14	$12,245	$12,245
127	22.51	22.71	0.20	3.3	14,951	91	1.14	$24,407	$21,493
127	22.71	22.99	0.28	4.0	14,951	88	1.34	$40,285	$35,474
127	22.99	23.18	0.19	3.3	14,951	90	1.13	$22,943	$20,203
127	23.18	23.33	0.15	3.3	14,951	90	1.13	$18,113	$16,641
127	23.33	23.81	0.48	4.0	14,951	88	1.33	$68,417	$60,247
127	23.81	24.00	0.19	5.9	14,951	79	1.50	$30,631	$26,973
127	24.00	25.39	1.39	4.2	14,951	85	1.35	$201,129	$177,111
127	25.39	25.57	0.18	3.3	14,951	86	1.07	$20,753	$18,275
127	25.57	25.74	0.17	5.2	14,951	78	1.32	$24,008	$20,264
127	25.74	26.95	1.21	4.2	14,951	81	1.29	$167,890	$147,842
127	26.95	26.96	0.01	4.2	14,951	80	1.28	$1,374	$1,374
127	26.96	27.05	0.09	4.2	14,951	80	1.28	$12,366	$12,366
231	15.62	15.76	0.14	2.3	1,084	68	0.63	$9,416	$6,998
231	15.76	15.98	0.22	2.3	1,084	68	0.63	$14,796	$10,104
231	15.98	15.99	0.01	2.3	1,084	68	0.63	$673	$500
231	15.99	16.05	0.06	2.3	1,084	68	0.63	$4,035	$2,999
231	16.05	16.12	0.07	2.3	1,084	68	0.63	$4,708	$3,499
231	16.12	16.20	0.08	2.3	1,084	68	0.63	$5,381	$3,999

Table 3. Estimated Incremental Overlay Thickness and Pavement Costs Resulting from Potential PCC Abandonment									
Route	**Begin MP**	**End MP**	**Miles**	**SN**	**Annual Additional Trucks**	**Percent Increase in ESALs**	**Incremental Inches of Overlay**	**Incremental Pavement Cost**	**Present Value of Cost**
231	16.20	16.30	0.10	2.3	1,084	68	0.63	$6,726	$4,999
231	26.20	28.11	1.91	2.3	1,084	59	0.55	$112,818	$87,483
263	9.00	9.05	0.05	2.9	7,952	22	0.26	$1,404	$1,000
263	9.05	9.11	0.06	2.9	7,952	22	0.26	$1,671	$1,190
263	9.11	9.12	0.01	2.9	7,952	22	0.26	$276	$197
263	9.12	9.24	0.12	2.9	7,952	22	0.26	$3,317	$2,363
270	0.00	0.06	0.06	4.8	4,620	35	0.54	$3,448	$2,789
270	0.06	0.12	0.06	4.8	4,620	26	0.41	$2,637	$2,134
270	0.12	0.70	0.58	4.8	4,620	26	0.41	$25,494	$20,625
270	0.70	0.75	0.05	4.8	4,620	26	0.41	$3,175	$3,043
270	0.75	1.57	0.82	4.5	4,620	23	0.39	$50,274	$46,188
270	1.57	2.19	0.62	4.4	4,620	19	0.33	$31,422	$30,118
270	2.19	2.27	0.08	4.4	4,620	14	0.24	$2,525	$2,525
270	2.27	2.31	0.04	4.4	2,166	4	0.06	$392	$392
270	2.27	2.40	0.13	4.4	2,454	3	0.05	$1,018	$1,018
270	2.40	2.48	0.08	2.7	2,454	6	0.07	$843	$742
270	2.48	2.60	0.12	2.7	2,454	8	0.09	$1,630	$1,376
270	2.60	2.67	0.07	2.7	2,454	8	0.09	$953	$953
270	2.67	2.84	0.17	5.5	2,454	4	0.07	$1,554	$1,312
270	2.84	2.96	0.12	6.0	2,454	4	0.08	$1,218	$945
270	2.96	2.98	0.02	5.8	2,454	4	0.08	$203	$133
270	2.98	3.13	0.15	5.8	2,454	4	0.08	$1,525	$998
270	3.13	3.25	0.12	3.6	2,454	4	0.05	$786	$560
270	3.25	3.43	0.18	3.6	2,454	4	0.05	$1,147	$853
270	3.43	3.97	0.54	3.6	2,454	4	0.05	$3,444	$2,560
270	3.97	3.98	0.01	4.1	202	0	0.00	$4	$3
270	3.97	4.10	0.13	4.1	2,252	3	0.05	$937	$697
270	4.10	5.33	1.23	5.9	2,252	5	0.09	$17,697	$12,607
270	5.33	5.63	0.30	5.9	2,252	6	0.11	$5,127	$3,652
270	5.63	5.75	0.12	5.9	2,252	6	0.11	$1,412	$1,006
270	5.75	8.11	2.36	5.9	2,252	6	0.11	$27,775	$19,787
270	8.11	9.26	1.15	5.9	2,252	6	0.11	$13,335	$9,500
271	8.38	8.44	0.06	2.6	431	14	0.15	$945	$945
272	16.52	16.78	0.26	1.6	454	4	0.03	$741	$741
272	16.78	16.93	0.15	1.6	454	4	0.03	$416	$416